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Editorial

"The Twentieth Century Is Canada's"

THE second of the JOURNAL's series of three articles on the electrochemical and electrometallurgical industries in Canada appears in this issue. Whereas the first dealt with these industries broadly across the whole Canadian scene, this one concentrates on the five easternmost of the ten provinces—Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland.

In all the world, Quebec stands unique, among political entities, in the generation and consumption of electric power. It generates and uses more per capita than does any whole nation. And the average price per kilowatt hour paid for industrial power sets an example; it is less than half a cent.

There are sound economic reasons for that happy situation, which prevails despite the fact that the major part of generating capacity in Quebec is investor-owned, and therefore subject to full federal, provincial, and municipal levies.

Chief of those reasons is the very fact of the rich availability of water power; topography and dependable precipitation have combined so that its development is relatively inexpensive. Second, stemming from the first, is the extent to which advantage has been taken of that availability; very large proportions of the power produced are consumed in great blocks by immense industries, with a resultant decrease in cost of delivery.

Relevant, too, is the force of dependable man power at hand, to direct that electrical energy into its industrial functions.

As well as Quebec, however, Canada's sea-washed provinces on the east coast are rapidly developing their resources and new technology, and are ready to march forward at every opportunity. Except Newfoundland, they are not as rich relatively in undeveloped water power as is Quebec, but they have at their doorsteps great stores of coal for thermal generation of electricity.

Moreover, there is a great will on the part of each province to further its own industrial expansion, particularly through the utilization of its natural resources in the production of electricity. And situated as they all are on the ocean shipping routes, they have an advantageous position for the importation of raw materials and the export of processed goods.

Canada, conscious of her part in world economy and in the defence of the free world, is also sensible of her own domestic growth. She has been told, and believes, that to an important degree "the Twentieth Century is Canada's." She is working to make it so, and welcomes new ideas and new development.

—A. W. WHITAKER, JR.

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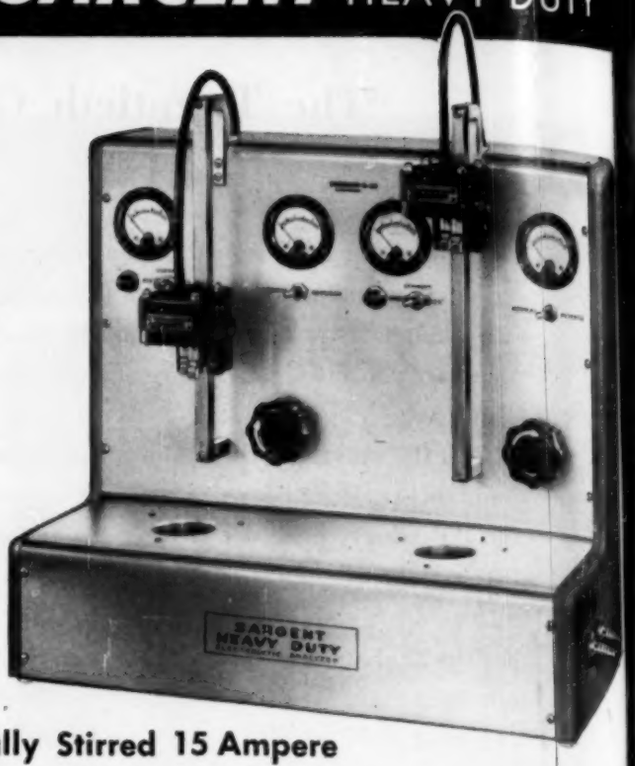

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ELECTROCHEMICAL AND ELECTROMETALLURGICAL INDUSTRIES OF CANADA

Part II. Quebec, The Maritime Provinces, and Newfoundland[1]

A. C. Holm[2]

Introduction

In this second of a series of three articles dealing with the electroproducts industries of Canada and their inseparable partners, the hydroelectric power developments, attention will be given to those projects which are located in the five eastern provinces—Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. In the next article, further enterprises of this nature will be described which are located in Ontario and the western provinces, including the Yukon and Northwest Territories. There is no political or economic significance in this arbitrary division of the nation into two halves; it just happens that this provides about an equal division of the subject matter. Canada's major power-consuming industries are located, in numbers and in size, more or less in direct ratio to the amount of power available; as Quebec has about one-half the power, so it has almost one-half of the large electroproducts industries. Ontario, with 30% of the installed power, British Columbia, with 10%, and Manitoba, with 5%, account for most of the remaining half.

The Province of Quebec

It is perhaps fitting that this tour of Canada's electroproducts industries and major power developments should begin in the Province of Quebec. Here began Canada's chemical industry in 1674, when one Nicolas Follin was granted the exclusive right to make potash; here water power was first harnessed for commercial mechanical uses, at the Petit Pré mill near Quebec City in 1691; and at Les Forges, on the St. Maurice River near Trois-Rivières, iron ore was first smelted in 1736 in the earliest commercial metallurgical plant of North America. Here, also, Canada's first electrochemical plant went into operation at Masson, near the junction of the Lièvre and Ottawa rivers, in the early 1890's, to produce electrolytic potassium chlorate. Today, the Province of Quebec leads all of Canada in the variety and value of its electrometallurgical and electrochemical products, as well as in the output of hydroelectric power.

The Province of Quebec, with an area of almost 600,000 square miles, greater than that of France, Germany, and Spain combined, is Canada's largest province. Its population of 4,269,000, over 80% of French descent, is second in numbers to that of Ontario only, and represents 29% of Canada's total. Its manufacturing industries produce about one-third of Canada's goods, its forests account for nearly one-half of Canada's pulp and paper output, and its mines produce about one-third of the nation's minerals in point of value. Quebec possesses nearly one-half of Canada's installed hydroelectric power and over one-third of the nation's remaining undeveloped potential. The undeveloped hydroelectric resources of Quebec, which are rated as being economically and technically exploitable, amount to about 19 million horsepower, greater than the hydro resources of any other Canadian province and equal to about 21% of the undeveloped hydroelectric resources of the whole United States.

Of the various factors that have operated to attract electrometallurgical and electrochemical industries to Quebec, the most important are the availability of raw materials, either indigenous or imported, excellent transportation facilities, and the huge resources of exceptionally low-cost, dependable, year-round electric power. The three physiographical divisions of the province—the Appalachian Highlands in the southeast, the St. Lawrence Lowlands, and the famed Laurentian Shield north of the St. Lawrence River—all contribute a great variety of minerals, of which the most important economically have been gold, copper, zinc, and asbestos. The electroproducts industries have so far made use mainly of Quebec's copper ores, with gold, silver, selenium, and tellurium as by-products, and of brucite, ilmenite, limestone, and sand. However, the province has at times produced large quantities of concentrates of zinc and lead, molybdenite, chromite, apatite and pyrite for export, which under favorable circumstances might someday undergo treatment within the province by electrothermic or electrolytic means. Tremendous reserves of high grade iron ore have been discovered in the Ungava (northeastern) region of Quebec, and are about to be exploited; electrothermic iron and steel production is a future possibility. The Precambrian rocks of the Laurentian Shield, covering some 90% of the area of Quebec, are believed to be a veritable storehouse of minerals; of this area perhaps only 10% has received adequate geological exploration—the potentialities in mineral wealth are thus enormous. What Quebec lacks in the way of native raw materials she is able to import cheaply, thanks to her unrivalled geographic location astride the mighty St. Lawrence River, which provides a ship channel of a minimum of 32½-ft depth almost 1000 miles inland from the Atlantic Coast to Montreal. The St. Lawrence canal-lock system gives access to the Great Lakes, westward from Montreal through a 14-ft channel; this may be deepened to 27 ft if the St. Lawrence Seaway project is adopted. During the shipping season of approximately seven months, vessels bring in many thousands of tons of raw materials, such as coal, salt, bauxite, phosphate rock, ilmenite, and steel scrap, for Quebec's electroproducts industries, and carry away ferroalloys, abrasives, calcium carbide, aluminum, magnesium, copper, titanium slag, and other products. In addi-

[1] This is the second in a series of three articles on Canada provided by A. C. Holm, Canadian Regional Editor.

[2] Shawinigan Chemicals Limited, Shawinigan Falls, Quebec, Canada.

tion, well-developed railway, highway, and air-line systems provide access to all inland points.

In the past, at least, imported Canadian or foreign raw materials have been equally as important to Quebec's electroproducts industries as her indigenous materials, and foreign markets, in the U. S. or overseas, have taken the major part of the production. As Quebec develops more of her own mineral deposits, and as the expanding Canadian economy provides more markets within Canada's boundaries, these relationships may change somewhat. Nevertheless, with Canada's heaviest concentration of industries and markets spread out for 4000 miles in a band of some 200 miles in width along the U. S. border, good transportation will remain of prime importance to Quebec, irrespective of any foreign trade considerations. But however important the access to raw materials and markets may be, in almost all cases the governing factor in the location of electrometallurgical and electrochemical industries in Quebec has been the availability of enormous amounts of exceptionally low-cost, dependable year-round hydroelectric power.

TABLE I. *Electric power by provinces, estimated to 12/31/53*

Province	Water resources (thousand hp)		Production 1953 (million kwhr)
	Developed	Undeveloped	
Quebec	7706	18,580	37,000
New Brunswick	162	251	1,135
Nova Scotia	171	32	1,120
Prince Edward Island	3	1	33
Newfoundland	304	3,056	1,200

Hydroelectric Power Developments in Quebec

The five most easterly of Canada's provinces—Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland (including Labrador)—together account for only about 20% of the nation's total area, and about 40% of the population. But they produce about 53% of Canada's electrical power each year.

Table I shows, for each of these eastern provinces, by preliminary estimates up to the end of last year (1953), the installed hydroelectric capacity, the known water power resources remaining to be developed, and the production of electricity from all sources during 1953.

As was illustrated in the first article in this series, almost all of the electric power in these provinces is from hydro stations, rather than thermal, and from central stations contributing to the public supply.

One of those provinces, Quebec, alone supplies about half of the power of the whole country. About twice the area of Texas but with only about half of that state's population, and accounting for about a quarter of Canada's people, Quebec possesses some of the largest hydroelectric generating stations in the world, and is continuing steadily to add to them. But so far, she has harnessed only about 29% of her known hydroelectric resources, and has a rich store of water power remaining within economic transmission distance of established industrial areas.

FIG. 1. Bird's eye view of sections 1 and 2 of the Beauharnois Generating Station which has now reached a total capacity of 1,400,000 hp. When No. 3 section is completed, the total capacity will exceed 2,000,000 hp.

Eighty-five hydroelectric generating stations, with individual capacities ranging from 2000 hp to 700 times that amount of energy, feed the immense amount of power into Quebec's industry, commerce, homes, and farms. That wealth of power, developed at relatively low cost, has been the principal factor in the conversion of Quebec's economy in just the past two or three decades, from one based principally on agriculture to one based largely on industry.

Thirty-five rivers, most of them flowing south and east from the Laurentian Divide toward the St. Lawrence, contribute the greater part of the power supply. The greatest of them, from the point of view of power production at pres-

ent, are the St. Lawrence, the St. Maurice, the Saguenay, the Ottawa and the Gatineau. The generating capacities of the first three of these are linked together by a power-grid which covers virtually all of the industrial sections of the province, permitting interchange of power as needed. Soon that grid will be extended, to reach from the Bersimis in the northeast, beyond the Saguenay, to the Windsor area of Ontario, opposite Detroit, in the southwest—a distance of 1000 miles.

The mightiest power-house in Quebec now is that called Beauharnois, only 20 miles from the center of Montreal. Owned by the Quebec Hydro-Electric Commission, it takes a large part of the flow of the St. Lawrence diverted through a 20-mile canal, and with the completion of additions by the end of last year, will have a capacity just under 1,420,000 hp. Another section, to yield between 660,000 and 770,000 hp, is envisaged for the future, to give Beauharnois an ultimate capacity of something over 2,000,000 hp.

On the St. Maurice River, which flows into the St. Lawrence about 100 miles northeast of Montreal, is a chain of six developed power sites in a 135-mile stretch of river. Part of the Shawinigan Water and Power Company's generating system, and successively using water from great storage reservoirs, they develop a total of 1,532,000 hp, and additions now being built at three of them will increase that total to almost 1,700,000 hp. The Shawinigan Company also has plans prepared for the development of four more sites on the St. Maurice, to develop almost 700,000 additional hp in the future.

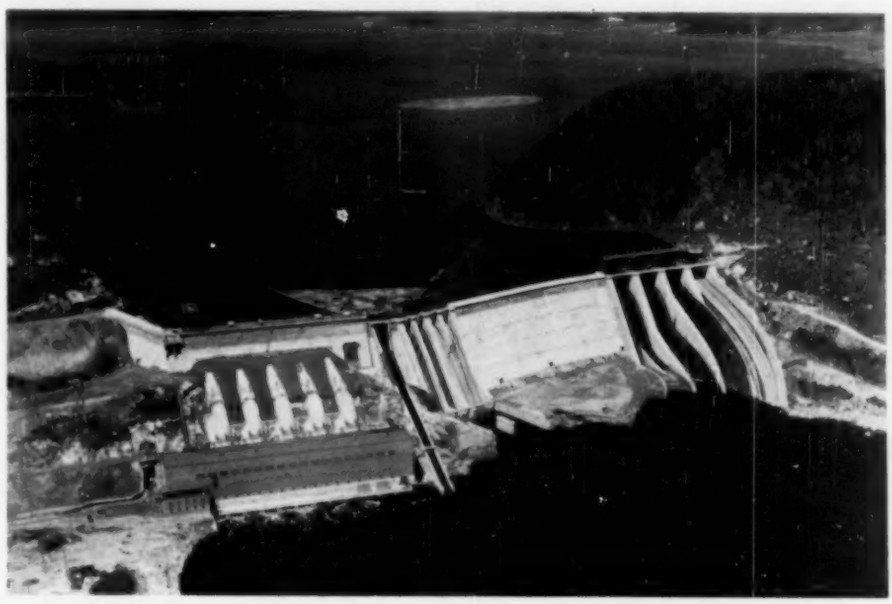

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FIG. 2. Aerial photograph of the newest of The Shawinigan Water and Power Company's chain of hydroelectric generating stations on the St. Maurice River at Trenche. The first five generating units were completed in 1951, and a sixth is being added now to give the plant a total capacity of 390,000 hp.

From north to south, and including the extra machines now being installed, the present St. Maurice River generating stations are:

Rapide Blanc	244,500 hp
Trenche	390,000 hp
La Tuque	272,000 hp
Grand'Mere	200,500 hp
Shawinigan Falls	416,500 hp
La Gabelle	172,000 hp

Together with Shawinigan's generating stations on other rivers, including those of the subsidiary Quebec Power Company, those plants supply not only the rich St. Maurice Valley—with its chemical plants (including the subsidiary Shawinigan Chemicals Limited, which has calcium carbide, chemical, and stainless steel divisions, and a neighboring associate producing resins and plastics), aluminum plants, the world's greatest concentration of pulp and paper mills, and many other industries—but also 25,000 square miles of the rest of Quebec. The little city of Shawinigan Falls alone, with a population of about 30,000, uses about as much electric power as does the City of Toronto, Ontario, which has about 30 times as many people.

The St. Maurice Valley has been frequently compared with the Tennessee Valley, because of its repeated use of the same water to produce electric power and commodities. But the average selling price of that power is far less than that of the TVA, even though it yields heavy federal, provincial, and municipal taxes and other levies.

Near the head of the Saguenay River and on its satellite streams, in the Lake St. John area of northeastern Quebec, are the great power plants of the Aluminum Company of Canada and its power subsidiaries. Much of the power generated goes to Alcan's immense aluminum smelter at Arvida (the largest in the world) and at Isle Maligne, but those generating stations contribute also to the public supply in the "Kingdom of the Saguenay."

Largest of the power plants is Shipshaw No. 2, with its 12 generating units of 100,000 hp each. It was built within a few months, early in World War II, to make possible the production of sorely-needed aluminum, and, like the other Alcan developments, it provides an outstanding example of raw materials being carried far to low-cost power; all of the materials of aluminum-making, except manpower and electric power, are imported hundreds or thousands of miles to the Saguenay—and profitably.

Closely tied with Shipshaw No. 2, and sharing its water supply, is Shipshaw No. 1, built earlier, with a capacity of 300,000 hp. Farther upstream, near the Lake St. John discharge, is the Isle Maligne plant, of 540,000-hp capacity; part of its power is sent under contract to the Shawinigan Company's system. And on the Peribonka, which flows into Lake St. John, are two new Alcan plants—The Chute du Diable and Chute à la Savane, each of 270,000 hp.

A number of other generating stations, of smaller size,

serve the area with its pulp and paper mills and other industries, its cities, towns, and farms.

East of the Saguenay is the Bersimis, which flows from the Laurentian Divide to the St. Lawrence. There, about 90 miles above its mouth, the Quebec Hydro-Electric Commission is now building a development which is to have a capacity of 1,000,000 hp, the first production being scheduled for 1956. A lake, the Cassé, is to be raised by 165 ft, flooding 200 square miles of bush-country, and a tunnel from its lower end will run 7½ miles to a subterranean power-house, where a townsite named Labrieville is now being built for the staff.

Part of the station's output is destined for the Gaspé Peninsula; to carry it there, transmission lines are being built 84 miles to Manicouagan; then four separate submarine conductors, 4000 feet apart, will cross the 31½ miles of the St. Lawrence at a maximum depth of 1200 ft, to Les Boules; and from there another transmission line will run 158 miles to Murdockville.

Some of the power, it is expected, will be transmitted 450 miles southwest, as far as Montreal, and some to the now-developing mining region of Chibougamau, about 200 miles to the west of Labrieville.

Forty miles downstream on the Bersimis, another development, of 500,000 hp, remains for the future.

On other tributaries flowing into the St. Lawrence over its 500-mile course from the area where Ontario, New York, and Quebec all join, down to the Gulf of the St. Lawrence, there are various hydroelectric developments, in a wide range of capacities. And on the Quebec-controlled sections of the 685-mile Ottawa, which joins the St. Lawrence at the Island of Montreal, are nine of them, with more scheduled for the future. (There are ten others on the Ottawa under Ontario's control.) Those Ottawa River plants on the Quebec side range in capacity from 112,000 hp at Chats Falls to just 2800 on the Winneway inflow at the upper reaches. They total about 440,000 hp.

On the fifth of Quebec's present main power rivers, the Gatineau, which flows into the Ottawa River opposite the city of Ottawa, are six hydroelectric developments owned by the Gatineau Power Company, and totalling 616,000-hp capacity. A considerable part of their power is sent across the provincial boundary to Ontario. The largest of those plants is the Paugan, of 238,000 hp.

Within Quebec during 1953, almost half a million hp of new hydroelectric capacity was scheduled for completion, and as much more within the following two years. Still in the future are such proposed developments as the Lachine Rapids plant, within the City of Montreal—an integral part of the St. Lawrence seaway plan, and with a potential 1,250,000 hp of hydroelectric capacity—and the Carillon, a few miles away on the Ottawa, with an estimated capacity of about half a million hp.

Thermal stations, in the Province of Quebec, already infinitesimal in importance of production, reached near-extinction, unable to compete with the phenomenally inexpensive operation of hydroelectric plants.

Electroproducts of Quebec

Aluminum

Canada's output of primary aluminum, representing nearly 25% of the world's production, is centered entirely in the Province of Quebec at present, in four smelters owned and operated by the Aluminum Company of Canada, Limited; a fifth smelter of this company is now under construction at Kitimat, British Columbia. The four Quebec smelters operating at capacity produce about 500,000 tons of primary aluminum per year. The amounts of power and raw materials consumed by these operations are truly staggering, and illustrate clearly why aluminum smelters must be located near sources of abundant cheap power and near shipping lanes. One ton of aluminum requires some 20,000 kwhr and nearly 7 tons of raw materials, including 4 tons of bauxite, for its production. The four Quebec smelters, now running at capacity, have a power load of some 1,600,000 hp and a raw material consumption equivalent to some 200 box car loads daily. Furthermore, over 80% of the product, i.e., some 1100 tons a day, is exported out of the country.

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FIG. 3. Smelter of the Aluminum Company of Canada, Limited, at Shawinigan Falls, Quebec. It has a capacity of 60,000 metric tons of aluminum ingot annually, and uses about 180,000 hp of electrical energy.

Bauxite is brought from British Guiana, 3000 miles away, and French Guiana, to Port Alfred on the Saguenay River within 20 miles of Arvida, the site of Alcan's ore-treating plant and its largest smelter. At Arvida, the bauxite is refined by the Bayer process to anhydrous alumina which is distributed to the various smelters. This process consumes soda ash, lime hydrate, and caustic soda, the latter from Alcan's caustic-chlorine plant at Arvida. Petroleum coke (shipped in from Texas and Gulf ports), pitch, tar, and metallurgical coke are used to prepare Soderberg anodes and pot linings. Fluorspar from Alcan's mines in Newfoundland

is beneficiated and treated with sulfuric acid to produce hydrogen fluoride, which, in turn, is reacted with calcined alumina to prepare aluminum fluoride. Hydrogen fluoride is also reacted with sodium aluminate to prepare synthetic cryolite, which supplements the natural cryolite imported from Greenland. Cryolite and aluminum fluoride are essential ingredients of the cell electrolyte, to which the refined alumina is added to be electrolyzed to metal. Alcan produces its own sulfuric acid (for HF) at Arvida, starting with the fluosolids-roasting of zinc concentrates from northwestern Quebec mines.

The approximate annual production rates and connected power loads of Alcan's four Quebec smelters at the present time are as follows:

	metric tons	*hp*
Beauharnois	32,000	100,000
Shawinigan Falls	60,000	180,000
Isle Maligne	80,000	250,000
Arvida	320,000	1,070,000*
Totals	492,000	1,600,000

* Includes caustic-chlorine and magnesium plants.

The first aluminum smelter in Canada was built in 1901 at Shawinigan Falls, Quebec, at the same time that the Shawinigan Water and Power Company began its development of the St. Maurice River at that site. This original plant, with additions, operated until 1945 when the pot-lines were dismantled and the plant converted entirely to the production of aluminum wire and cable. The Arvida smelter, on the Saguenay River some 40 miles below Lake St. John, was started in 1925, to get a site closer to deep-water shipping and to hydro resources which could be reserved almost exclusively for the great expansion of the aluminum industry which was then expected. This smelter was gradually enlarged involving also the construction of powerhouses, deep-water wharves, railways, and a townsite. During World War II, when Canadian aluminum production was stepped up from 75,000 tons in 1939 to 450,000 tons in 1943, the Arvida Works grew at a tremendous rate to become the largest aluminum smelter in the world. Today it covers an area 1½ miles long by ¾ mile wide; it has been reported to have 25 pot-lines with a total of 2500 pots.

During World War II a smelter was built at Isle Maligne (to which futher capacity was added in 1952); an additional smelter at Shawinigan Falls, which is the one now operating there; a smelter at La Tuque on the upper St. Maurice River, since dismantled; and the fourth, presently operating smelter at Beauharnois on the St. Lawrence River southwest of Montreal.

With its existing smelters in Quebec operating at capacity, the Aluminum Company of Canada is planning ahead for eventual possible doubling of its output when its new smelter site in British Columbia will have reached its ultimate development.

Magnesium

Quebec lays claim to the first production in North America of magnesium metal in commercial quantities, in 1915 by the Shawinigan Electro Metals Company, a now defunct subsidiary of the Shawinigan Water and Power Company. Today, one of Canada's two magnesium producers is located in Quebec, at the Arvida plant of the Aluminum Company of Canada. Alcan started pilot-plant production by the electrolytic process from magnesium chloride in 1943, expanded output to about 1000 tons per year in 1945, and in 1952 stepped up its capacity to about 4000 tons annually. Part of this output is under contract to the United Kingdom Ministry of Materials; part is used by Alcan for alloying purposes, and the remainder is sold.

The raw material for Alcan's magnesium is brucitic limestone from its mine at Wakefield, Quebec, northwest of Ottawa, which is treated to yield a concentrate with about 90% MgO. At Arvida this is processed to magnesium chloride, using some of Alcan's chlorine supplied from its caustic-chlorine plant at that location.

Copper

Electrolytically refined copper is produced by Canadian Copper Refiners Limited at Montreal East. This company is about 92% owned by Noranda Mines Limited and receives crude copper from Noranda's huge smelter at Noranda, Quebec, as well as from the smelter of the Hudson Bay Mining and Smelting Company, at Flin Flon, Manitoba. Approximately 70,000 tons of Noranda anode copper and 40,000 tons of Flin Flon blister copper are processed annually at the Montreal East refinery. This plant will also receive in a couple of years crude copper from the new smelter of Gaspé Copper Mines, a Noranda subsidiary, now being built in Holland township in the Gaspé region not far from the St. Lawrence Gulf port of Mont-Louis. Besides the conventional electrolytic cell installations, Canadian Copper Refiners also has an electric arc furnace for copper melting. Power is supplied by "Hydro-Quebec" (Quebec Hydro-Electric Commission).

While Quebec has a number of active copper mines, there is only one copper smelter and one electrolytic refinery in the province at present. Canadian Copper Refiners has been in operation since 1931.

Selenium and Tellurium

These two metals are recovered as by-products of the electrolytic refining of copper by the Canadian Copper Refiners Limited at Montreal East. They collect in the copper anode slimes, are separated chemically, and refined electrolytically. Production of selenium runs about 100–150 tons annually and of tellurium 20–30 tons. The Montreal East refinery, with a rated annual capacity of 450,000 lb of selenium, is said to be the largest selenium plant in the world.

Cerium (Mischmetal)

Since 1940 Shawinigan Chemicals Limited at Shawinigan Falls, Quebec, has produced commercial cerium metal by a fused salt electrolysis method. The product is a mixture of rare earth metals containing about 50% cerium, used in various alloys and principally as a pyrophoric alloy with iron in lighter-flints. The raw material is imported rare earth chloride salt made from Brazilian monazite. Capacity of the plant at Shawinigan Falls is about 60,000 lb per year.

Chlorine and Caustic Soda

Three producers of electrolytic chlorine and caustic soda are located in Quebec—Canadian Industries Limited at Shawinigan Falls, Dominion Alkali and Chemicals Limited at Beauharnois, and the Aluminum Company of Canada Limited at Arvida. Salt is brought in to Quebec from other parts of Canada or from the U. S. The chlorine and caustic soda output is to a large extent consumed by Quebec's pulp and paper industry.

The Canadian Industries Limited plant at Shawinigan Falls went into operation in 1939. It employs mercury cells,

Shawinigan power, and some 215 employees. Besides direct sales of caustic soda, chlorine, and hydrogen gas, this plant provides chlorine for HCl gas and various organic chemicals produced at this site.

The Dominion Alkali plant at Beauharnois, owned by Dominion Tar & Chemical Company Limited, produces liquid chlorine and 50% liquid caustic soda; it employs Kreb's mercury cells and power from Hydro-Quebec. Operation began in 1949, and press reports at that time placed the rated annual capacity at about 18,000 tons of chlorine and 22,000 tons of caustic soda.

The Arvida plant of the Aluminum Company of Canada was the first commercial plant to utilize the improved Mathieson horizontal stationary mercury cell; operation began in late 1947. Production is now at a rate of about 20,000 tons chlorine and 25,000 tons caustic soda annually. Alcan uses the caustic soda in its Bayer alumina process, and a small part of its chlorine for magnesium chloride; the remainder of the chlorine is liquefied and sold.

Hydrogen Peroxide

The only production of electrolytic hydrogen peroxide in Canada is carried on at Shawinigan Falls, Quebec, by Canadian Industries Limited. Output of "100-volume" hydrogen peroxide began in 1935; a 50% expansion of production was undertaken in 1952. The process is reported to be based on the electrolysis of ammonium bisulfate solution.

Electrolytic Hydrogen and Oxygen

At the Shawinigan Falls plant of Canadian Resins and Chemicals Limited, a leading producer of synthetic vinyl resin and plastic compound (Vinylite), a stand-by electrolyzer is installed to furnish pure hydrogen, which is required for this firm's production of vinyl resin (Vinylite) plasticizers and intermediates. This unit employs mechanical rectification of alternating current for its d-c supply, and, at the time of its installation in 1949, was one of the first applications on this continent of this type of rectifier.

Electrolytic Chlorates

The first commercial electrochemical plant in Canada was set up in the early 1890's at Masson, Quebec, by A. Maclaren, S. P. Franchot, and W. T. Gibbs to produce potassium chlorate by an electrolytic process. When this plant was destroyed by fire, the enterprise was directed to other electro products, and in 1897 the Electric Reduction Company Limited was formed with British capital to produce phosphorus at nearby Buckingham. During World War I, production of potassium and sodium chlorates was resumed by this company. In 1935, the firm was reorganized as the Electric Reduction Company of Canada Limited, its present style. During World War II, production of chlorates was extended to include perchlorates of potassium and ammonia by use of sodium perchlorate from a platinum-copper electrolysis of sodium chlorate solution. In 1950–1951 production facilities for sodium and potassium chlorates were expanded to handle some 20,000 tons per year; some of this was destined for export markets, while some was ear-marked for the domestic pulp and paper industry to supply chlorine dioxide bleach.

Electric Furnace Phosphorus

The Electric Reduction Company of Canada Limited has carried on the production of phosphorus at Buckingham, Quebec, since 1897, and is thus the oldest operating electrochemical company in Canada. It is also one of the few remaining English-controlled firms in Canadian chemistry, being held by Albright and Wilson of Oldbury, England, who also control Oldbury Electrochemical Company, producers of phosphorus products, in the United States.

Production of phosphorus at Buckingham was originally based on phosphate deposits in the locality. At that time, Quebec led the world in the production of phosphate rock; mining operations ceased, however, with the development of more cheaply-produced Florida phosphates. Present production of phosphorus at Buckingham utilizes imported phosphate, and is on a scale of some 8000 tons per year. Besides yellow phosphorus, "Erco" now produces at Buckingham phosphoric acid and a large number of phosphates and pyrophosphates, as well as phosphorus sesquisulfide. By-products of phosphorus furnace operations are ferrophosphorus and rock wool. Erco also generates some of its own hydroelectric power on the Lièvre River.

At Varennes, Quebec, on the south shore of the St. Lawrence River below Montreal, the Electric Reduction Company of Canada is bringing into production a new electric furnace phosphorus plant. The first units, consisting of two 15,000-kw furnaces, will increase Erco's phosphorus output by about 14,000 tons per year. Electric power is being supplied by the Shawinigan Water and Power Company.

Calcium Carbide

The sole producer of calcium carbide in the Province of Quebec is Shawinigan Chemicals Limited, whose plant at Shawinigan Falls is the largest of its kind in the British Commonwealth. This company traces its origin to the Shawinigan Carbide Company, which went into operation at Shawinigan Falls in 1904 as one of the first customers of the Shawinigan Water and Power Company, utilizing electric power generated in Shawinigan's first hydroelectric power development on the St. Maurice River at this site.

With T. L. ("Carbide") Willson, the Canadian-born inventor of the commercial carbide process, as its vice-president, the Shawinigan Carbide Company in its early years set up 12 ingot-type furnaces with a combined capacity of 2000 tons of carbide per annum. Later, this enterprise took the name of Canada Carbide Company and came under the control of the Shawinigan Water and Power Company. Today, its descendant, Shawinigan Chemicals Limited, a wholly-owned subsidiary of the Shawinigan Water and Power Company, operates five furnaces at Shawinigan Falls with an installed capacity of over 200,000 tons carbide per annum, for which it employs over 100,000 hp.

Shawinigan Chemicals Limited quarries its own limestone, burns it to lime in eight large rotary kilns, produces some of its own coke by an unique process, and charges lime and coke to the continuously operating carbide furnaces, of which the largest is operated at 22,000 kw. The furnaces are equipped with Soderberg electrodes, Shawinigan being the first carbide producer on this continent to install this type of electrode. Anthracite coal for the preparation of these electrodes is calcined in continuous, vertical electrical retorts with the coal acting as resistor. Only approximately 20% of Shawinigan's output of calcium carbide is now sold as such, the remainder being used to generate acetylene gas on which a gigantic organic chemical enterprise has been built up at Shawinigan Falls. Chief organic products are acetic acid and acetic anhydride, vinyl acetate, ethyl acetate and other solvent esters of acetic acid, butanol and vinyl acetate synthetic resins.

At Shawinigan Falls this Company produces also alloy steels in electric furnaces, cerium metal, and acetylene black. Shawinigan Chemicals Limited operates the world's largest plant and the only one on this continent for the production, by thermal decomposition of acetylene, of acetylene black, which is an important constituent of dry cells because of its high electrical conductivity and absorptive capacity for electrolyte. Products of Shawinigan Chemicals Limited are sold around the world, with the U. S. being the largest consumer of its exports.

Shawinigan Chemicals Limited together with its parent, the Shawinigan Water and Power Company, has long been prominent in electrochemical and electrometallurgical development work. Besides developing their carbide furnaces from the early single-phase, batch, ingot type to the present three-phase, continuous, tapping furnaces, the Shawinigan companies at various times have carried on research and development work on electrically powered units such as a gas producer, coal calcining retort, coking retort, lime burner, and electric steam boilers; on production of electrolytic magnesium, manganese and cerium metals, and electrolytic manganese dioxide; on electric furnace smelting of ilmenite ore, and on electric furnace production of ferrosilicon, mineral wool, and fused phosphate fertilizer, as well as on other projects in which electrical energy played a prominent role. Some of these developments have attained commercial applications, notably electric steam boilers, calcining retorts for anthracite coal, magnesium and cerium metals, and electric smelting of ilmenite ore. But for the past 50 years, the name 'Shawinigan' is perhaps best known to electrochemists in connection with the production of calcium carbide, of which over 3,000,000 tons have been produced in the last 30 years alone at Shawinigan Falls.

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FIG. 4. The calcium carbide division of Shawinigan Chemicals Limited at Shawinigan Falls, Quebec, the largest producer of carbide in the British Commonwealth. It uses about 100,000 hp of electrical energy. Beside it, to the right, is the stainless steel and alloys division of the company.

Ferroalloys

In Canada production of ferroalloys is all carried on in electric furnaces. In the Province of Quebec are located two plants devoted to ferroalloy production, while at three other plants a ferroalloy is produced as a by-product of other operations.

St. Lawrence Alloys and Metals Limited is located at Beauharnois, Quebec, and obtains power from the nearby Beauharnois generating station of the Quebec Hydro Electric Commission. Among its products are ferrosilicon, silicon metal, silicocalcium, and zirconium alloys.

Electro-Reagents (Quebec) Limited, also located at Beauharnois, came into operation in 1953. This plant produces high-silicon ferrosilicon, at present mainly for its parent company, Dominion Magnesium Limited, of which it is a wholly owned subsidiary. This ferrosilicon is required for the production of magnesium by the Pidgeon process, operated by Dominion Magnesium at Haley, Ontario. This new $1 million plant is managed by Atlantic Metallurgical Corporation, a Quebec subsidiary of the Chromium Mining and Smelting Corporation Limited.

Electric Reduction Company of Canada Limited produces ferrophosphorus as a by-product of phosphorus production at Buckingham, and similar output will result from its new plant at Varennes, Quebec.

Shawinigan Chemicals Limited recovers a 20% silicon ferrosilicon as a by-product from its carbide furnaces at Shawinigan Falls.

Simonds Canada Abrasive Company Limited has a by-product 12% silicon ferrosilicon from its aluminous abrasive furnaces at Arvida, Quebec.

Mineral Wool

The Electric Reduction Company of Canada Limited has produced mineral wool using as a raw material electric furnace slag from its phosphorus production at Buckingham.

Artificial Abrasives and Refractories

The Canadian Carborundum Company Limited produces crude silicon carbide at Shawinigan Falls. Started in 1917, this plant was, and may still be, the largest plant in the world producing crude carborundum.

Electro-Refractories and Abrasives Canada Limited produces crude silicon carbide at Cap-de-la-Madeleine, Quebec (on the St. Maurice River near Trois-Rivieres). A 50% expansion of plant capacity was completed in 1951. Production capacity is about 5000 tons per year, with a power load of about 6000 hp.

Norton Company also operates a plant at Cap-de-la-Madeleine, to manufacture silicon carbide abrasive ("Crys-

tolon"). First operated in early 1951, this plant doubled Norton's Canadian output of "Crystolon."

The above three plants are located in the St. Maurice Valley and draw their power from the Shawinigan Water and Power Company.

Simonds Canada Abrasive Company Limited operates a plant at Arvida to produce fused aluminum oxide abrasive. This company, a division of Simonds Saw and Steel Company, has an installation of eight 550 kw, Higgins-type aluminous abrasive furnaces. At capacity, the power load is about 6800 hp. Production includes regular, semifriable, and heavy duty types of abrasive; ferrosilicon is a by-product.

Titanium Slag and Iron

Discovery of a tremendous ore body in Quebec of ilmenite containing some 88% of combined titanium and iron oxides, and the development of an electric smelting process to treat this ore, led to the formation of the Quebec Iron and Titanium Corporation in 1948 and the subsequent construction of an electric smelting plant at Sorel, Quebec, which is the only one of its kind in the world. The process is essentially a selective reduction of iron oxide from the ore, forming as one product a slag containing some 70% TiO_2 and little iron oxide, and a fairly pure iron, containing chiefly carbon and sulfur as impurities, as the second product. Because of the high melting point of the slag, the operation is carried out in an electric furnace. The need for large amounts of relatively low-cost power and access to deep-water shipping governed the selection of the site at Sorel, where a large block of power was made available by the Shawinigan Water and Power Company.

Ore is mined in the Allard Lake region and shipped over a 27-mile company-owned railway line to Havre St. Pierre on the north shore of the St. Lawrence, whence it is carried by vessel to Sorel. The Sorel smelter has been designed to treat some 1500 tons of ore daily at full capacity, the plans calling for five electric arc smelting furnaces and two electric arc iron refining furnaces. Molten slag from the smelting furnaces is cooled, crushed, and shipped out by vessel or by rail, while molten iron tapped from the smelters is charged to the refining furnaces for a desulfurizing operation, after which it is cast. The slag is sold for the production of titanium pigments, while the iron is sold as a good-grade melting stock for steel production. Experimental operation of the first smelting furnace began in late 1950.

The Quebec Iron and Titanium Corp. is jointly owned by the Kennecott Copper Corporation and the New Jersey Zinc Company.

Iron Powder

At Cap-de-la-Madeleine, near Trois-Rivières, Quebec, another new enterprise has started up fairly recently to produce iron powder for powder metallurgy applications. At the plant of Ferrum, Limited (incorporated in 1947) an electric furnace is used to melt down steel scrap with graphite, the metal being then cast in water into pellets which are subsequently ball-milled. The resulting product, an iron powder with less than 0.1% carbon, is sold for use in powder metallurgy.

Electric Furnace Steel

The availability of low-cost hydroelectric power on a 24-hr basis has given rise to a flourishing business in the electric furnace melting of steel for castings and ingots in the Province of Quebec. About one-quarter of Canada's electric steel furnaces are to be found in this province. Operations and equipment are of a conventional nature; the products cover a wide range of applications in carbon and alloy steels. The following are all located within the Province of Quebec: Canadian Tube & Steel Products Limited, Montreal; Canadian Car and Foundry Company Limited, Montreal; Sorel Industries Limited, Sorel; Sorel Steel Foundries Limited, Sorel; Griffin Steel Foundries Limited, St-Hyacinthe; Lynn MacLeod Metallurgy Limited, Thetford Mines; Manganese Steel Castings Limited, Sherbrooke; Canadian Unitcast Steel, Limited, Sherbrooke; Dominion Brake Shoe Company Limited, Joliette; and Shawinigan Chemicals Limited (Stainless Steel & Alloys Division), Shawinigan Falls.

The foregoing list of 17 products of the electrochemical and electrometallurgical industries of Quebec is believed to cover all of the direct electroproducts and to enumerate their various producers within the province. This survey is confined to the *direct* electrochemical and electrometallurgical products; no attempt is made to include the many derivatives made from these products. Nor has any attention been given to the large consumers of power for mechanical purposes or for electric steam boilers—in both of which applications Quebec's huge pulp and paper industry leads the field.

The Province of New Brunswick

Moving eastward from Quebec on our tour of Canada's electroproducts industries, we find in the Province of New Brunswick a good potential for such industries in the future, but no establishment of this nature at the present time. The lack of electrochemical and electrometallurgical industries in New Brunswick may be attributed mainly to lack of cheap power in quantity and lack of suitable mineral production. However, recent power surveys and mineral explorations indicate the possibility of a vast improvement in this situation.

The Province of New Brunswick has an area of nearly 28,000 square miles and a population of about 536,000, i.e., about 3.7% of Canada's population. It produces about 2% of Canada's manufactures, about 0.8% of its minerals, and about 1.5% of its electric power. Products of its forests have been of prime importance (pulp and paper and lumber); other manufactures, agriculture, fisheries, and mining add to its income. In St. John it has one of Canada's main Atlantic ports, open the year round.

New Brunswick has an installed hydroelectric capacity of about 162,000 hp, including the newly-completed station at the Tobique Narrows. All told, there are eight hydroelectric plants of more than 2000 hp each. Central stations, as opposed to industry-owned plants producing power for their own use alone, generate about two-thirds of the total electrical energy annually; about one-third of that central station production is thermally generated. While the undeveloped hydroelectric potential at various sites has been estimated at 251,000 hp, further studies may reveal that a much larger output may be feasible. The St. John River, if given extensive regulating and storage facilities, has been estimated to have a potential of 700,000 hp alone. The cost of its development has been estimated at over $220 millions, however, and agreement would have to be reached with the neighboring State of Maine and the Province of Quebec on the use of its waters. Still more remote are the proposals for harnessing the giant tides of the Bay of Fundy, the world's highest tides, on New Brunswick's southeastern coast. At the head of the Bay of Fundy (in Chignecto Bay) one scheme envisages the development of 2.3 million hp, at a cost of

$400 millions. Others have advocated a location at Cape Split, Nova Scotia, at the entrance to Minas Basin, while still others have argued the merits of a tidal-power development on Passamaquoddy Bay, near the Maine coastal border, which would yield an estimated 1 million hp at an initial cost of $100 millions. The size and cost of such projects makes their realization under present conditions quite improbable; however, few would be so rash as to assert that such large amounts of power would never be needed in this area and that the cost would always be prohibitive. Tidal power, if developed at the head of the Bay of Fundy, would appear to be within economic transmitting distance of any point in the Provinces of New Brunswick, Prince Edward Island, and Nova Scotia.

Mineral production in the Province of New Brunswick has consisted mainly of coal, gypsum, cement-making materials, peat moss, a little petroleum and natural gas, with sporadic mining of iron and manganese ores. But in the past two years an unprecedented amount of base-metal exploration has taken place in the northern part of the province, resulting in many promising finds of lead, zinc, copper, pyrite, and manganese. In the vicinity of Bathurst it is reported that a tremendous ore body has been discovered, containing chiefly sulfides of lead and zinc together with copper and silver, which has created speculation on the prospects of a fully-integrated smelter for this area.

These possibilities of the availability of indigenous ores and of moderate or even tremendous amounts of electric energy, existing coal supplies, and the province's favorable location with regard to shipping and foreign markets, all combine to give promise of some type of electroproduct output in New Brunswick in the future.

The Province of Nova Scotia

What has just been said about New Brunswick's prospects of electrometallurgical or electrochemical production, may, with slight alteration, also be applied to the Province of Nova Scotia. Except for a limited production of electric furnace steel, Nova Scotia lacks any electroproducts output today. But she possesses ample reserves of coal, salt, limestone, gypsum, and barytes as raw materials, a location which would permit her to import and export large tonnages cheaply, and the possibility of almost unlimited generation of electric power based on indigenous coal or on the harnessing of the mighty tides of the Bay of Fundy. Any or all of these factors may be expected to lead to eventual expansion of her electroproducts output.

The Province of Nova Scotia, with an area of about 21,400 square miles and a population of 663,000 stands second only to tiny Prince Edward Island in density of population. With about 4.5% of Canada's population, she produces about 2.5% of its manufactures, 4.8% of its minerals, and about 1.5% of its electrical energy. She produces over 30% of the nation's coal, 84% of its gypsum, and 99% of its barite.

Nova Scotia's internal hydroelectric resources have been almost fully developed. The developed power stands at about 171,000 hp, the undeveloped power at about 32,000 hp. Steam power derived from coal is in the ascendancy, the thermal installations now being about 154,000 hp, with more scheduled. With her coal mining now becoming more mechanized, Nova Scotia is hoping to keep power costs low. However, perhaps her best prospect for low-cost power in quantity would lie in the much-debated possibility of harnessing the tides in the Bay of Fundy, which wash a large part of her western coastline.

While bituminous coal of excellent quality accounts for over 80% of Nova Scotia's mineral production, she also turns out important quantities of salt, gypsum, and barytes, and has large deposits of limestone in reserve. There is a small output of base-metal (lead-zinc) ore, and showings of copper and tungsten ore. But her greatest industry, iron and steel, is built up on iron ore imported from Newfoundland. With her excellent ice-free harbors, Nova Scotia is in a good position to import other raw materials for processing, but has done little of this as yet. Fisheries, agriculture, forest products, and miscellaneous manufacturing all contribute to the province's wealth.

Electric steel melting furnaces are to be found at the following locations:

Dominion Iron and Steel Limited, Sydney, N. S.—This is a subsidiary of the giant Dominion Steel and Coal Corporation, Limited, which mines coal in Nova Scotia and iron ore in Newfoundland, and on these has built up a fully integrated iron and steel industry in Nova Scotia. Besides open-hearths, it operates at Sydney one 10-ton electric furnace, of the top-charging type with 4000 kw transformer capacity. This produces special quality forging steels, low alloy and low carbon steels.

Maritime Steel Foundries Limited, New Glasgow, N. S.—This company operates an electric steel melting furnace of 4-ton size for the production of castings.

The Province of Prince Edward Island

This is the smallest of Canada's Provinces, with an area of 2184 square miles and a population of 106,000. The land is extremely fertile and about 85% of it is cultivated. Agriculture and fisheries provide the main income, with manufacturing being confined to the preparation of dairy products. Lacking in forests, minerals, and sizeable streams, there is no lumbering or mining carried on, and water power sites are almost nonexistent. There is about 2300 hp of hydro power installed and about 21,700 hp of thermal power. Needless to say, there are no electroproducts industries on "The Island."

The Province of Newfoundland

The island of Newfoundland with its mainland dependency, Labrador, comprises Canada's newest province, having entered into Confederation in 1949. As a good deal of Newfoundland and the major part of Labrador has not yet been adequately surveyed with regard to water power and mineral resources, it is impossible to predict what the chances are of establishing electroproducts industries, at present nonexistent, on the island or on the mainland. From early indications, however, there would appear to be no lack of either minerals or water power for development, and it will probably be the hard economic facts of production costs, shipping charges, and market possibilities that will determine whether or not electroproducts industries could thrive in this somewhat remote area.

The island of Newfoundland has an area of about 42,700 square miles while Labrador comprises 112,000 square miles; all but some 8000 of the combined population of 383,000 are residents of the island. Mineral production, to date all from the island, accounts for some 2.6% of Canada's total, and consists mainly of ores containing zinc, iron, lead, fluorspar, copper, silver, and gold, in decreasing order of value. Hematite has been mined for 50 to 60 years from the Wabana deposit on Bell Island, and although over 40 million tons have been extracted for export to Canada, the U. S., and to Europe, the known submarine reserves are estimated to be

sufficient for several centuries at present rates. The complex lead-zinc-copper ore at Buchans has been mined heavily since 1928, and concentrates are shipped to the U. S. and Europe. Newfoundland supplies over 90% of Canada's fluorspar. Limestone is another important product. A tremendous amount of mineral exploration work has been proceeding in Newfoundland and Labrador since confederation, and reports of widespread mineral occurrences are common. In Labrador, a huge deposit of high-grade hematite has been discovered in the now-famous Labrador Trough along the Quebec border. Copper, titanium, nickel, lead, zinc, asbestos gypsum, and other minerals all appear to be future possibilities.

Fishing, pulp and paper and lumbering, and water power also contribute heavily to Newfoundland's development, and these, together with mining, are all being vigorously pushed today by Newfoundland's government and by several large corporations who have obtained extensive exploration and development concessions on the island and on the mainland.

The development of water power in the province is favored both by topography and climate. Of Canada's five easternmost provinces, Newfoundland ranks second to Quebec in developed and potential hydroelectric power resources. Some 304,000 hp have already been developed, and the undeveloped potential has been estimated at over 3 million hp. Surveys of water power resources are still incomplete and little definite information has been published thereon as yet. On the south-central coast of the island it is estimated that some 400,000 hp could be developed from several sites; there are other possibilities elsewhere. In Labrador, one of the largest single undeveloped power sites in the world is found on the Hamilton River at Grand Falls, some 315 ft high. This river, with several others in Labrador's interior, promises a potential of several million horsepower if their regulation and development prove feasible.

Newfoundland has a rather tenuous narrow-gauge railway line some 700 miles long running between the two main ports of St. John's on the east and Port aux Basques on the west. It serves, amongst others, the paper mills at Cornerbrook and Grand Falls, the Buchans mine, and the international civil airport at Gander. The main shipping ports are Bell Island (for iron ore), Botwood (pulp, paper, and Buchans concentrates), Cornerbrook (pulp and paper), St. John's and Port aux Basques. The latter two are usually free of ice all winter.

Newfoundland will have many problems to solve in the exploration, development, and marketing of her many resources. But if the vigor and enthusiasm of present activity is an indication, these problems will be solved in time, and Canada's newest province should enjoy a wide-spread industrialization and sound prosperity—some of it possibly based on electroproducts.

NOTE:—*In the third and final article of this series it is proposed to deal with the individual electroproducts industries and power developments in the Provinces of Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia, and in the Yukon Territory and the Northwest Territories.*

Feature Section

Coulometry—Related Phenomena of Electrolysis and Current-Sweep Polarography[1]

N. Howell Furman[2]

Introduction

For several recent years, a number of new or modified aspects of electroanalytical methods have been studied in our laboratories. Recently, emphasis has shifted to the determination of substances in the milligram range and lower, down even to the submicrogram range. Our first war-time research in 1942 evolved a procedure that consisted in the electrolysis of traces of metals such as copper, lead, cobalt, cadmium, iron, nickel, zinc, etc., into a small mercury cathode, followed by removal of the mercury by distillation and polarographic or spectrophotometric examination of the residue (1). During war-time, it was not possible to explore other techniques for estimating the metals that were present in the mercury cathode. It was recognized that, without exceedingly careful technique and proper admission of air (oxygen) during the distillation, the more volatile metals such as cadmium might be lost. Subsequently, Cooper (2) investigated the determination of other metals amalgamated with mercury by making the amalgam the anode in a capillary dropping assembly and taking polarograms. This technique gave good qualitative information and semiquantitative results, even on five-component mixtures. The results with simpler amalgams appear to be of interest in connection with the determination of the diffusion coefficients of metals in mercury as solvent medium (3).

Recently, Rogers and coworkers (4) and Cooke (5) have had good success in using coulometric or polarographic techniques of combined methods in estimating submicrogram amounts of metals electrolyzed into mercury.

Schmidt (6) has found that controlled potential electrolysis of a dilute amalgam as anode permits one to electrolyze out and determine elements such as copper, lead, cadmium, and zinc, whereas the passive metals, cobalt and nickel, in presence of excess of iron do not electrolyze out. He has demonstrated that amounts of the first four metals ranging from a few micrograms up to several milligrams may be removed from the mercury and then estimated polarographically. Presumably the passive metals may then be recovered by distillation of the mercury and estimated by polarographic, spectrophotometric, or other methods.

The developments thus far mentioned have been concerned primarily with electrolysis and polarography. The present paper is concerned primarily with coulometry.

Coulometry

Coulometric methods have been open for development since the publication by Faraday of his fundamental laws of electrolysis. For a great many years, the classical coulometric method with cells in series has been studied in courses in physical chemistry, or for fundamental standardization purposes (7). The technique has been advocated for the precise determination of equivalent weights (8). Recently there has been a very decided increase in interest in various coulometric methods for analytical and other purposes.

Controlled potential electrolysis in conjunction with series oxyhydrogen coulometers has been developed by Hickling (9) and by Lingane (10).

A fundamental idea that is essential to a number of modern developments in coulometry for analytical purposes is that of the addition of a substance to a solution for the purpose of generating therefrom at 100% current efficiency a reagent to carry out a definite chemical reaction, thus dispensing with the necessity of preparing and storing standard solutions. This mode of approach seems to be due to Szebelledy and Somogyi (11) who studied brominations and neutralizations in this fashion. They did not appear to realize the full advantages and simplicity of the approach since they used indicators to detect end points and a series silver coulometer for current integration. They achieved a high degree of precision.

It is of interest that some of the present popularity of the coulometric method is due, in part at least, to early studies on surface coatings and corrosion films. Among the earliest of modern studies along this line is one by Grower (12) on the thickness of tin coatings on copper wires. His apparatus is represented schematically in Fig. 1. He was able to differentiate between the pure tin layer and the underlying layer, and also visually when the intermediate layer of copper-tin alloy was dissolved and the pure copper color appeared. Gas coulometers were used for the quantitative measurements.

A very significant development is contained in a study by Campbell and Thomas (13) on the thickness of experimental corrosion or tarnish films of oxide of sulfide or mixtures of oxide and sulfide on pure copper or silver foils. This paper clearly demonstrates the principle of electrolysis at constant current with simple measurement of time to a potentiometric end point or a succession of such points. This type of study has recently been repeated by Allen (14) who found that purest copper, after cleaning by electrolytic polishing and transfer to a system that could be evacuated, developed a film of cuprous oxide of average thickness of 6.5 Å, whereas exposure to air from 0.5 hr typically developed a 15 Å film, whereas after several hours in dry air the films grew to 20–25 Å thickness. The effect of different techniques of washing after polishing could be clearly examined.

The anodic stripping of electrolytic coatings by a constant current to a potentiometric cutoff point was developed by Francis (15) as a convenient method for estimating the thicknesses of electrodeposited coatings of one metal on another.

The evolution of the modern application of the coulometric method to general classes of reactions in solution received its major recent advance from the extensive series of researches by Swift and his associates (16) who have given the name "coulometric titration" to the process of development of a

[1] Palladium Medal Address delivered at the Wrightsville Beach Meeting, September 15, 1953.

[2] Princeton University, Department of Chemistry, Princeton, New Jersey.

reagent at constant current to a determinable end point. Other similar developments that should be mentioned are by Trishin (17) who measured amounts of dissolved metals in mercury at constant current by time measurement to a determinable cutoff point. Epstein, Sober, and Silver (18) neutralized acids to an end point by generating alkali from potassium bromide at constant current. Trishin has used the name electrochronometric analysis for the constant-current process with measurement of time to an end point. This name covers both titrations of soluble systems as well as the deposit on, or removal from, electrodes at constant current.

Our own contributions to the field have included the development of a convenient electronic apparatus for providing constant current (19) and an exploration of the electrogeneration of ferrous (20) or ceric (21) ion. In these studies potentiometric technique with a vacuum-tube voltmeter or a

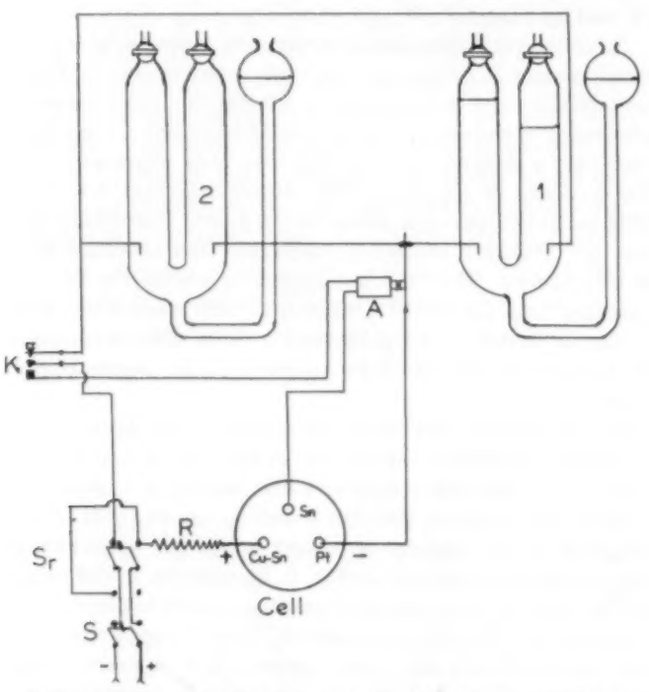

FIG. 1. Grower's thickness tester. Oxyhydrogen coulometer, [1], is in series until the anode Cu-Sn is electrolyzed away until its surface is substantially different from that of the pure tin indicator electrode, Sn. Relay, [A], then throws coulometer [2], into the circuit. The current is stopped when the copper-tin surface of electrode Cu-Sn changes visually to pure copper. The circuit is opened manually.

*p*H meter was used to detect the end point. In the course of this work it was realized that the amperometric technique with polarized electrodes, used by Swift and associates, was more sensitive and that a compensated potentiometric end point or titration to a suitable potential of a potentiometric system might be adaptable to work in the low microgram range.

This sensitive compensated end point (22) was applied to the estimation of vanadium (V) in presence of uranium (VI) by electrolytically generated ferrous ion in the vanadium range 400 down to 2 micrograms in the presence of a large excess of uranium (23). In the range from 20 to 2 micrograms, the average error was about 1%.

When applied to the coulometric determination of uranium that had been reduced to the quadrivalent state by cadmium amalgam coulometric titrations with electrolytically generated ceric ion (24) in sulfuric acid medium, the errors were larger and of the order of 2.6% in the estimation of 0 microgram of uranium or 4.8% (avg) when 5 micrograms were estimated.

Thus far the most sensitive method that we have tested consisted in the coulometric estimation of permanganate (25). This process as used probably consisted in the storage of a slight amount of pregenerated ferrous ion in the ferric reagent, reaction of the ferrous with the added permanganate and restoration of the ferrous ferric equilibrium that existed prior to addition of the permanganate. The average error in estimating 0.1 to 0.2 micrograms of manganese in this fashion was 3.5% (9 determinations). In the range from 0.08 down to 0.01 microgram, the average error was not appreciably larger but from 0.08 down to 0.003 microgram the average error was 9%.

The indication in all these sensitive determinations is essentially amperometric in character with a passage of the galvanometer through zero current reading at the end point. This research indicates that the concentration range that is accessible for titrations by essentially the classical compensated end point (equal and opposite potential to indicator

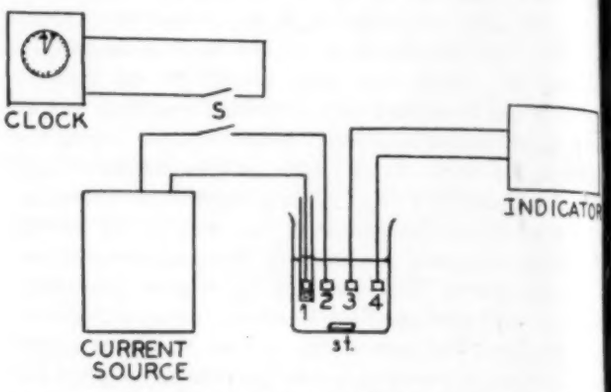

FIG. 2. Coulometric circuit with electrometric indicator. A constant current from the current source and the precision electric time clock are thrown into the circuit simultaneously by the switch, [S], electrode, [1], is sheltered from the solution by a porous diaphragm, and the reagent is generated at electrode, [2]. The electrodes [3], [4] serve to indicate the end point either by potentiometric, amperometric, or other feasible type of indication. St. represents a stirrer bar driven by a magnetic stirrer.

system) of Müller (26) is very far down in the micro region, and it is probable that with an adequate microburet the lower range of titrations could be extended appreciably.

The major limitations to the extension of the coulometric titration process to the submicrogram range seem to lie in kinetic factors at extreme dilutions, slow electrode processes, and adsorption phenomena. Our observations appear to indicate that the slow approach toward equilibrium that one encounters wherever intermittent potentiometric balancing is practiced is largely eliminated by allowing the indicator electrode to take up or deliver an infinitesimal continuous current near the end point.

In the majority of applications that have been made with electrolytically generated ceric ion, the precision and accuracy appear to be less satisfactory than with processes in which a reversible system is involved in the final part of the titration. An interesting feature of these sensitive methods is that no elaborate temperature control nor very exacting experimental conditions have been involved. Purity of reagents and removal of dissolved air (oxygen) have been important.

When oxidation by ceric ion is applied to organic substances, it is necessary to use fresh cerous solution for each

determinations, whereas in many inorganic estimations small samples can be added to the solution and titrated without adding a fresh generating solution. Hydroquinone has been titrated successfully with errors averaging 0.5% in the range 200–300 micrograms of hydroquinone, 2% in the 12–90 microgram range, and 3% in the 1–3 microgram range (27).

Determinations with photometric indication in the ultraviolet range have been made by J. W. Handleman (unpublished) for the bromination process. The coulometric generator electrodes were inserted in the solution that was contained in the special cell described by Bricker and Sweetser (28). The bottom of this cell was of dimensions to fit the 1-cm compartment of the Beckman DU spectrophotometer. Brominations of 60–80 micrograms of resorcinol gave an average error of 0.4%. These studies make it apparent that one might combine all the advantages of photometric estimations with the coulometric determination principle, such as generation of excessive known amounts of reagent beyond the end point.

Current-Sweep or Potentiometric Polarography

Polarization curves on background medium and medium plus reagent are useful in coulometry as well as in various electrometric methods. It was found profitable to build a number of resistor decades of such characteristics that current could be increased by definite increments. Current-voltage curves were then taken by reading emf between reference electrode and generator electrode positioned to avoid or minimize *IR* drop (29). Later, a continuously variable current was applied more conveniently with the aid of a triode, the grid of which was varied in voltage to give an essentially linear current in the plate circuit. The actual electrode and cell to be used in a coulometric process could be thus used to determine current efficiency for the generation of a reagent. This procedure gives a conservative estimate of the permissible conditions for generation with substantially 100% efficiency. A comprehensive discussion and analysis of the utilization of polarization curves in analytical electrochemistry has recently appeared from the Ecole Superieure Laboratory in Paris (30).

In sweeping the current it was observed that polarograms could be constructed manually at rotating platinum electrodes with less tendency to form time maxima or rounded humps at the usual point where maxima are apt to occur when the voltage is increased point by point. Later experiments (unpublished) with automatic current-sweep were disappointing with solid electrodes, but preliminary observations indicate that there may be desirable features in the current-sweep idea as applied to the dropping capillary mercury electrode. These possibilities are being explored further by R. N. Adams.

Other Coulometric Techniques

The coulometric titration technique may obviously be utilized with any valid type of end-point indication. Various potentiometric, amperometric, and photometric procedures have been tested and there are many other possibilities which have already been used or will lend themselves to give automatic end points, actuate control devices, etc. Carson has developed automatic devices (31) and has used the derivative polarographic idea (32) in good advantage for indication when the solution must be heated during coulometric titration.

Automatic methods.—Analysis and probably control of gas or liquid streams is possible by mixing sample and reagent in a fixed ratio by a proper pump or other mixing device. The current that is needed to keep the mixture continually titrated to a definite index point may be calibrated in terms of concentration of the substance titrated. The general form of apparatus is indicated schematically in Fig. 3. This type of coulometric application was first described by Shaffer and coworkers (33).

Automatic titration to an end point is possible in batch operations, and a suitable analytical system has been described by Carson (34).

Coulometric generation of standard solutions.—It is possible to generate certain solutions coulometrically at constant current in a portion of the apparatus that is external to the solution to be titrated. DeFord and associates (35) have demonstrated the desirability of this procedure by generating alkali from sodium sulfate, the cathode and anode process being separated by a diaphragm of glass wool in an inverted U-tube with inlet tube at the bottom of the U. This mode of procedure obviously is capable of extension through many branches of volumetric analysis. The resultant change in volume of the solution titrated is a possible unfavorable factor for micro applications.

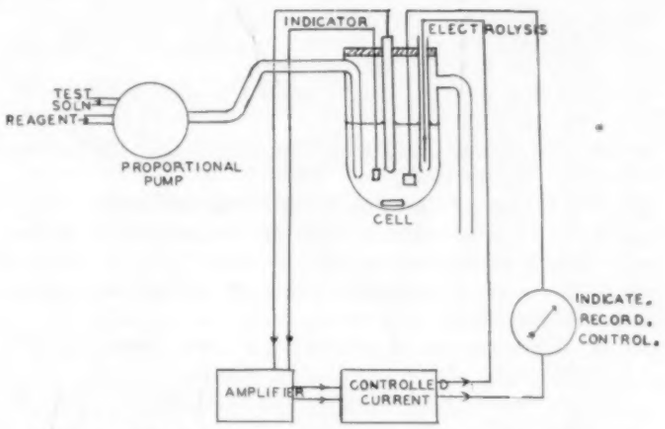

FIG. 3. Coulometric indication in testing flow systems. The indicator circuit activates the current control so that the mixture of reagent and test solution or gas is titrated constantly to maintain a predetermined value of the indicating system.

The constant current-time principle has been used from time to time to generate hydrogen or oxygen to be added as a known component of a gasous mixture, to prepare dilute standard solutions of various sorts, and probably for other uses.

This review has not been designed to be all-inclusive but rather to describe some recent developments that have made coulometry of increasing analytical usefulness. The majority of papers that have not been mentioned here can be readily located through the papers cited or through a review paper that appeared recently (36).

Acknowledgment

This award of the Palladium Medal is obviously in recognition of a long-continued group effort involving colleagues and students. It is a pleasure to acknowledge the writer's thorough training in research in analytical electrodeposition under the guidance of the late Professor L. W. McCay, and the excellent instruction in electrochemistry, especially potentiometry, conductometry, and classical coulometry that was given by Professor Emeritus G. A. Hulett in his graduate laboratory course. This instruction led to association with Dr. I. M. Kolthoff in the authorship of "Potentiometric Titrations." With few exceptions, the doctoral theses of the writer's graduate students have been in the field of electrochemical studies as applied in chemical analysis. A number of

undergraduate researches of supervisees have also been in this field, and a number of these have been published. These various efforts have served as the basis for the award.

REFERENCES

1. N. H. Furman, C. E. Bricker, and B. McDuffie, *J. Wash. Acad. Sci.*, **38**, 159 (1948).
2. N. H. Furman and W. C. Cooper, *J. Am. Chem. Soc.*, **72**, 5667 (1950).
3. W. C. Cooper and N. H. Furman, *ibid.*, **74**, 6183 (1952).
4. S. S. Lord, Jr., R. C. O'Neill, and L. B. Rogers, *Anal. Chem.*, **24**, 209 (1952).
5. W. D. Cooke, *ibid.*, **25**, 512 (1953).
6. W. E. Schmidt, Dissertation, Princeton University, Princeton, N. J. (1953).
7. E. B. Rosa and G. W. Vinal, *Bull. Bur. Standards*, **13**, 479 (1916); *Proc. Nat. Acad. Sci. U. S.*, **3**, 59 (1917).
8. E. L. Quinn and G. A. Hulett, *J. Phys. Chem.*, **17**, 770 (1914); an illustration of this type of research is given in this work.
9. A. Hickling, *Trans. Faraday Soc.*, **38**, 27 (1942).
10. J. J. Lingane, *J. Am. Chem. Soc.*, **67**, 1916 (1945).
11. S. Szebelledy and Z. Somogyi, *Z. anal. Chem.*, **112**, 313, 323, 332, 385, 391, 395, 400 (1938).
12. G. G. Grower, *Am. Soc. Testing Materials, Proc., II*, **17**, 129 (1917).
13. W. E. Campbell and U. B. Thomas, *Trans. Electrochem. Soc.*, **76**, 303 (1939).
14. J. A. Allen, *Trans. Faraday Soc.*, **48**, 273 (1952).
15. H. T. Francis, *This Journal*, **93**, 79 (1948), C. T. Kunze and A. R. Wiley, *ibid.*, **99**, 354 (1952).
16. S. W. Sease, C. Niemann, and E. H. Swift, *Anal. Chem.*, **19**, 197 (1947).
    R. J. Myers and E. H. Swift, *J. Am. Chem. Soc.*, **70**, 1047 (1948).
    D. J. Meier, R. J. Myers, and E. H. Swift, *ibid.*, **71**, 2341 (1949).
    R. A. Brown and E. H. Swift, *ibid.*, **71**, 2717 (1949).
    W. S. Wooster, P. S. Farrington, and E. H. Swift, *Anal. Chem.*, **21**, 1457 (1949).
    W. J. Ramsay, P. S. Farrington, and E. H. Swift, *ibid.*, **22**, 332 (1950).
    P. S. Farrington and E. H. Swift, *ibid.*, **22**, 889 (1950).
    R. P. Buck, P. S. Farrington, and E. H. Swift, *ibid.*, **24**, 1195 (1952).
    P. S. Farrington, D. J. Meier, and E. H. Swift, *ibid.*, **25**, 591 (1953).
17. F. I. Trishin, *Zhur. Anal. Khim.*, **3**, 21 (1948).
18. J. Epstein, H. A. Sober, and S. D. Silver, *Anal. Chem.*, **19**, 675 (1947).
19. C. N. Reilley, W. D. Cooke, and N. H. Furman, *ibid.*, **23**, 1030 (1951); *ibid.*, **24**, 1044 (1952).
20. W. D. Cooke and N. H. Furman, *ibid.*, **22**, 896 (1950).
21. N. H. Furman, W. D. Cooke, and C. N. Reilley, *ibid.*, **23**, 945 (1951).
22. W. D. Cooke, C. N. Reilley, and N. H. Furman, *ibid.*, **23**, 1662 (1951).
23. N. H. Furman, C. N. Reilley, and W. D. Cooke, *ibid.*, **23**, 1665 (1951).
24. N. H. Furman, C. E. Bricker, and R. V. Dilts, *ibid.*, **25**, 482 (1953).
25. W. D. Cooke, C. N. Reilley, and N. H. Furman, *ibid.*, **24**, 205 (1952).
26. E. Müller, "Elektrometrische (potentiometrische) Massanalyse," 6th ed., p. 52, Steinkopf (1942); lithoprinted by Edwards Bros., Ann Arbor, Mich. (1945).
27. R. N. Adams and N. H. Furman, *Anal. Chem.*, **25**, 1361 (1953).
28. C. E. Bricker and P. B. Sweetser, *Anal. Chem.*, **24**, 978 (1952).
29. R. N. Adams, C. N. Reilley, and N. H. Furman, *ibid.*, **25**, 1160 (1953).
30. R. Gauguin, *Anal. Chim. Acta*, **7**, 172 (1952).
    R. Gauguin, *ibid.*, **7**, 360 (1952).
    R. Gauguin and G. Charlot, *ibid.*, **7**, 408 (1952).
    R. Gauguin and G. Charlot, *ibid.*, **8**, 65 (1953).
    J. Badoz-Lambing, *ibid.*, **7**, 585 (1952).
31. W. N. Carson, Jr., *Anal. Chem.*, **25**, 466 (1953).
32. C. N. Reilley, W. D. Cooke, and N. H. Furman, *ibid.*, **23**, 1223 (1951).
33. P. A. Shaffer, Jr., A. Briglio, and J. A. Brockman, Jr., *ibid.*, **20**, 1008 (1948).
34. W. N. Carson, Jr., *ibid.*, **25**, 226 (1953).
35. D. D. DeFord, J. N. Pitts, and C. J. Johns, *ibid.*, **23**, 938 (1951); *ibid.*, **23**, 941 (1951).
36. P. S. Tutundzic, *Anal. Chim. Acta*, **8**, 168 (1953); *ibid.*, 182, 184 (1953).

Nathaniel Howell Furman—The Man and His Work

R. M. Burns[1]

I can think of no more agreeable way to end a vacation in Maine than to fly down here today to tell you what I know about the 1953 Palladium Medalist. I first met Howell Furman in 1919 upon my return to Princeton from the war. He too was out of uniform and had joined the Princeton faculty as assistant professor after having taught at Stanford University. A native of New Jersey, his trip to California had impressed him with the wild and Gargantuan qualities of the West. He has been satisfied ever since to live in the East.

Our medalist's choice of New Jersey as a state in which to be born may be considered as very early evidence of prophetic vision, for New Jersey with its billion dollar chemical industry leads the nation in chemical manufacture and in number of chemists. The village of Lawrenceville, near Princeton, has the distinction of claiming him as a native son. Here as a boy, he worked summers in his father's old fashioned general store, the town's headquarters, which also housed the post office. An additional source of income was the sale of lost golf balls which, in spare moments, he hunted on the Lawrenceville School golf course across the street from his home. No doubt it was this early acquaintance with golf balls that led to his later addiction to the game. Not that he has ever let golf seriously interfere with chemistry. Indeed he originated the saying that: "He who shoots 100 has no business playing golf; he who shoots 80 has no business." I am not sure where this leaves President Eisenhower.

To go back to Lawrenceville, it was natural that he should go to the well-known boy's school there and on to Princeton. At the latter, he impressed both teachers and members of the class of 1913, and was thought likely to succeed.

Another important vital statistic concerns Lawrenceville, for there lived in that town the attractive Hannah Henderickson, sister to Furman's close companion at Lawrenceville

[1] Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.

and Princeton. Now, the results of a joint research, carried out in Duluth by investigators from the universities of Maryland and Minnesota, show that 42% of the marriages in Duluth were of couples living within 20 blocks of each other. Those familiar with the size of Lawrenceville will understand that on this basis alone the marriage of Miss Henderickson and our medalist was inevitable. This took place in 1919, and now, 34 years later, I merely observe that both must be complimented for good judgment. There is a son, Richard Howell, and a daughter-chemist, Carol, who married and as Mrs. Samuel Kirkwood, wife of a biochemist, has provided three grandchildren. The principal attraction of Vermont where the Furmans spend the summer is the visit with these youngsters and their parents. Of course, there are golf courses in the Green Mountains and Lake Champlain has offered sailboat-racing. As far as I can discover, Howell Furman has not walked the 260 miles of the Long Trail—Vermont's greatest asset; he prefers the automobile as a means of locomotion. He indulged in his first Chevrolet in 1924 and, since that time, has proved himself General Motors' best customer by wearing out eight more Chevies.

This stick-to-it-iveness is characteristic of our medalist. It finds expression in his loyalty to friends, to Princeton, and to his profession, in the diligence and care with which he prepares his lectures, and the persistence with which he pursues his researches. Studious, reserved, but friendly, Furman is well known for his dry humor and his apt and entertaining stories. He is so conscientious and dependable that he finds himself all too often appointed to some committee, the members of which usually permit him to do all of the work.

When he entered the Princeton Graduate School, Furman came under the influence of Professor Leroy McCay who had been a student of Bunsen. A teacher of great enthusiasm and energy, insatiable curiosity, and strong optimism, McCay inspired his student with these qualities and Furman, in turn, has transmitted the spirit of research and the urge to teach to present-day students. Commenting on graduate training, Furman has stated:

"The spirit of research is, I believe, essential to the best of advanced university training, provided one always keeps in mind the fact that our primary purpose is to assist in the education of our students."

The importance of experimentation and knowledge of the scientific literature has always been stressed at Princeton. Furman's remote predecessor, John MacLean, who became professor of chemistry in 1795 and was thus the first to hold this post in an American college, offered the following advice to the president of Yale College: "Be as obliging as to inform Dr. Dwight that I am of the opinion that it is impossible for me to acquire even a slight knowledge of chemistry without either making experiments or seeing them performed and that to become proficient in the science will require extensive reading . . . the most valuable part of chemical writings is to be found in the publications of the different learned societies in Europe. . . ."

As chairman of the Department, Professor Furman has added administrative work to his teaching and research by merely adding more working hours to the day. He has devoted fruitful effort to long range planning as well as to the more immediate administrative affairs. With his usual conscientiousness, he has given much thought to the problems that confront academic institutions and their young scholar-scientists and teachers these day. However, in spite of many duties and responsibilities, he continues to find time for personalized teaching and never misses spending an afternoon a week in the laboratory instruction of undergraduate students.

Early in his career, Furman recognized the need for improved textbooks for teaching analytical chemistry and so he translated for American use Kolthoff's books on indicators and volumetric analysis. A little later, he wrote with H. H. Willard "Elementary Quantitative Analysis, Theory and Practice," the leading college text on the subject (shortly to come out in its 4th edition). It has been translated into German and Spanish. Finally, Professor Furman is Editor-in-Chief and contributor of several chapters of Scott's "Standard Methods of Chemical Analysis," that essential reference work for all analytical laboratories.

Our medalist's scientific work has found publication in more than 80 papers. He has applied and extended the use of electrochemical principles to the purposes of analytical chemistry with great imagination and skill. He is distinguished for his pioneer work in the field of potentiometric titrations. Pointing out the value of electrochemistry in the teaching of chemical analysis, he has proceeded to illustrate the thesis by originating new and more sensitive electrometric methods based on potentiometry, amperometry, coulometry, and polarography. A large part of Dr. Furman's research has been associated in one way or another with oxidation-reduction reactions. Early potentiometric studies utilizing ceric sulfate as an oxidant are described in more than a dozen papers which show the advantages of this now widely used reagent. From this potentiometric basis, it was natural that he should undertake projects in the related fields of electrodeposition, polarography, and coulometric titrations.

Dr. Furman and his students have developed techniques along these lines that are of great value in trace metal analysis. One scheme involves the electrodeposition of trace metals in a mercury cathode, distillation of the mercury, and polarographic analysis of the residue. Another method consists in coulometric titration with electrolytically generated ceric ions in a ferric sulfate medium. In this case, quantities of uranium as small as 5 micrograms can be determined with good accuracy and precision by the oxidation of quadrivalent uranium, using a cadmium amalgam reductor for the prior reduction of the uranium from the hexavalent to the quadrivalent state and employing a sensitive amperometric end point.

Professor Furman contributed significantly to the Manhattan—or atomic bomb—project. Faced with the problem of detecting uranium and transuranic elements in the presence of almost every other element and of determining many of the common elements in the presence of uranium, the group under his leadership successfully devised the necessary procedures. Among the several techniques that have been declassified and summarized in a National Nuclear Energy monograph is that of extracting trace elements as cupferrate complexes with organic solvents. It is not exaggeration to say that Professor Furman's efforts in the field of extraction were instrumental in the development of the large-scale production of vital ingredients for the atomic bomb. That this work involved long hours and required communication of reports and ideas as well as experimentation and administrative duties is evident from the fact that the night girl at Western Union used to say: "As soon as I get the call from N. H. Furman, I know it is time to close up the office."

Our medalist has received many honors and has engaged in many extracurricular activities. Phi Beta Kappa and Proctor fellow at Princeton, Robert Stuart Brokos fellow for study abroad; at various times associate editor of *Chemical*

Reviews and Analtyical Edition of *Industrial and Engineering Chemistry* and advisor to its successor *Analytical Chemistry*. He was the first recipient of the Fisher Award for achievement in analytical chemistry. A member of many technical societies, he joined The Electrochemical Society in 1920 and has published several papers in its TRANSACTIONS. He was president of the American Chemical Society during its Diamond Jubilee year, and thus, in connection with the International Congress of Pure and Applied Chemistry, represented American chemistry in its largest world-wide interaction. The following excerpts from his presidential address indicate his broad vision of the responsibilities of chemists in modern society:

"It is certain that future efforts of chemists and chemical engineers will, if properly utilized, be a most powerful constructive force for the future welfare of mankind. . . . Let us resolve to use our skills and talents together with whatever persuasive powers we may possess toward every constructive activity for the future benefit of mankind."

A distinguished Princeton classmate of Professor Furman adds the following touch to the portrait I have tried to sketch:

"To my mind, Howell's outstanding trait is his unselfishness. However, his unselfishness is of a rare type, so unobtrusive that one may have to know him for years before becoming aware of it. He is extremely helpful to other people, but he gives his help so casually that he is likely to go unthanked. He talks very little about doing the right thing, but simply does it as a matter of course, demanding nothing for himself in return.

"Of all the incidents in life which have built up my faith in human nature, the outstanding one was the action of the American Chemical Society in selecting as its President a man who had asked for himself as little as Howell Furman."

Over the fireplace in the Frick Chemical Library at Princeton is an inscription attributed to the mathematician Ptolemy which may be translated "He is not dead who hath given new life to Knowledge." In this light, our medalist radiates great vitality.

So Ladies and Gentlemen, I give you Nathaniel Howell Furman, Educator, Scientist, Gentleman, and leader in American analytical chemistry.

MANUSCRIPTS AND ABSTRACTS FOR SPRING MEETING

Manuscripts are now being received for the Spring Meeting of the Society, to be held at the La Salle Hotel in Chicago, May 2, 3, 4, 5, and 6, 1954. Subjects to be covered at the technical sessions will be Electric Insulation, Electronics, Electro-Organic Chemistry, Industrial Electrolytics, and Theoretical Electrochemistry.

To be considered for this meeting, triplicate copies of manuscripts or abstracts (not to exceed 75 words in length) must be received at Society headquarters, 216 West 102nd Street, New York 25, N. Y., *not later than January 15, 1954*.

Current Affairs

Bureau of Standards Vindicated in AD-X2 Dispute

A special committee of the National Academy of Sciences has confirmed the much-disputed finding of the Bureau of Standards that a battery additive, AD-X2, is worthless but harmless, and has found the Bureau's battery work is "excellent."

The report released by Secretary of Commerce, Sinclair Weeks, on November 13 was unequivocal in praising the work of the Bureau of Standards and in confirming the Bureau's finding that AD-X2 is without merit. The report states, "We conclude from our studies and investigations that the quality of the work of the National Bureau of Standards in the field of lead acid battery testing is excellent. This statement is made without reservations. Our opinion is that the quality of the work of the Bureau in this field is better now than at any time in the past. This is partly because of the closer cooperation of the Bureau's Statistical Engineering Laboratory with the Electrochemical Section in the design and interpretation of battery tests."

Summary of Finding on AD-X2

Following is the Committee's finding on AD-X2: "We find no data obtained from any well-designed scientific experiment which is inconsistent with the hypothesis that AD-X2 behaves like a corresponding mixture of sodium and magnesium sulfates, and is substantially neutral in its effect upon a lead acid storage battery. These experiments included a total of over 400 cells, a substantial number of which were selected or approved for tests by Pioneers." Conclusion on AD-X2: "We conclude that the relevant data now available to us regarding the effects of AD-X2 are adequate to support the position of the National Bureau of Standards that the material is without merit." The committee recommended that no further tests be undertaken by the committee or under its supervision.

This culminates one of the most bizarre episodes in the history of the Bureau. Last March the Secretary of Commerce, Sinclair Weeks, brought down on his head a storm of protest when he dismissed Allen V. Astin from his post as Director of the National Bureau of Standards, giving as one of his reasons his feeling that the Bureau had been unfair in its testing of the battery additive. Astin defended the Bureau's work. The widespread publicity attending the dispute raised considerable question in the press as to the integrity and objectivity of the personnel at N. B. S.

ECS Protest

The Electrochemical Society, as well as the majority of the nation's other scientific societies, promptly protested and asked a review of the facts by a competent scientific body. Secretary Weeks temporarily reinstated Dr. Astin and asked Dr. Detlev W. Bronk, President of the National Academy of Sciences, to appoint a committee to review the work of the Bureau in the field of battery additives and to make such additional tests as might be needed to settle the question as to the merits of AD-X2. Since that time Craig Shaeffer, formerly Assistant Secretary of Commerce, who had investigated the problem for Mr. Weeks and had recommended Astin's dismissal, has resigned his post and Dr. Astin has been permanently reinstated. Secretary Weeks has expressed himself as gratified at the vindication of the Bureau and at Dr. Astin's willingness to remain as Director.

In 1948, Pioneers, Inc., manufacturers of AD-X2, protested the fact that the Bureau of Standards would not make a specific exception in the case of their product from its general finding that no battery additive had been proved to have substantial merit. Since there was no indication that AD-X2 was different in any important way from many other similar mixtures of sodium and magnesium sulfates which were known to be worthless, the Bureau was unable to change its position. After the Post Office Department started proceedings to issue a fraud order against Pioneers, Mr. Jess Ritchie, president of the company, appealed to the Select Committee on Small Business of the U. S. Senate to investigate alleged discrimination against his product. Further tests of AD-X2 were made by N. B. S. during the summer of 1952 which, the Bureau concluded, confirmed their earlier findings. Pioneers charged that these tests had been improperly conducted and refused to accept the report. The Senate Committee then arranged for independent tests to be made at the Massachusetts Institute of Technology. A report of this work, issued by the Senate Committee on December 18, 1952, was accompanied by a press release and a commentary by Dr. Keith J. Laidler, consultant to that committee and a former consultant to Pioneers. Dr. Laidler stated that the M.I.T. tests "demonstrate beyond a reasonable doubt that this material is in fact valuable and give complete support to the claims of the manufacturer." He then went on to criticize severely the tests made by the Bureau of Standards and other government agencies and to question the objectivity of the investigators. These charges made headline news in the nation's papers and after the change of administration in January, the new Secretary of Commerce asked his assistant Mr. Shaeffer to look into the Bureau's handling of the case, with the result that in March Dr. Astin was asked to resign.

On May 4, Secretary Weeks asked Dr. Bronk to appoint a committee of scientists to review the entire problem. In July, the committee, headed by Zay Jeffries, retired Vice-President of the General Electric Company, Chemical Division, was commissioned to review the work of the Bureau of Standards relating to Battery AD-X2. They were instructed to proceed as they thought best, to appraise the Bureau's work and procedures, and to perform such addi-

tional tests as seemed necessary and desirable. The ten-man committee, made up of scientists from seven universities, the Rockefeller Institute, and two industrial concerns, found itself faced with thousands of pages of testimonials, statements, reports, and experimental data. After careful and detailed study of the available material, the Jeffries Committee decided that the differences between treated and untreated cells, if any, were too small to be detected in any except the most carefully controlled tests. The M.I.T. report, so highly regarded by Dr. Laidler and so frequently quoted as evidence of the Bureau's errors, was found by the Committee to be too limited in scope to determine the merits of the additive. It was noted that the report does not even purport to evaluate AD-X2 and that the tests were only exploratory in nature and "appear not to have been designed for the purpose of evaluating AD-X2."

Only 4 Well-Controlled Tests Made

The Jeffries Committee based its findings on four sets of well-controlled tests, the general design of which was proposed by Mr. Ritchie. Three of these tests were done for Pioneers, Inc. The remaining data were those obtained by the Bureau of Standards since 1951. In reports which came to light after the close of the Senate Small Business hearings in June, Professor T. P. Dirkse, of Calvin College, Grand Rapids, Michigan, and Dr. R. S. Dean of the Chicago Development Company of Riverdale, Maryland, had each concluded that their respective tests had shown no significant difference between cells treated with AD-X2 and untreated controls. The United States Testing Company of Hoboken, New Jersey, reported some effects which might have indicated some merit for the additive. Careful study of the supporting data convinced the Jeffries Committee that one of the differences reported probably resulted from poor control of experimental conditions and that the other effect, while statistically significant, is of no practical importance and, as shown by the Bureau's studies, is one which disappears with subsequent charging.

The Committee found no effects of the additive large enough to be of practical value and such effects as were observed corresponded to well-known laws of physical chemistry. In no case was the behavior of AD-X2 different from that of a corresponding simple mixture of sodium and magnesium sulfates.

The membership of the Committee was as follows: Zay Jeffries, Chairman, Vice-President (Retired), General Electric Company, Chemical Division; Elmer K. Bolton, Director of Chemical Department (Retired), E. I. du Pont de Nemours and Company; William G. Cochran, Professor of Biostatistics, Johns Hopkins University; J. P. Fugassi, Professor of Physical Chemistry, Carnegie Institute of Technology; John G. Kirkwood, Professor of Chemistry, Yale University; Victor K. La Mer, Professor of Chemistry, Columbia University; Lewis G. Longsworth, Member, Rockefeller Institute for Medical Research; Joseph E. Mayer, Professor of Physical Chemistry, University of Chicago; Fred E. Terman, Dean, School of Engineering, Stanford University; Samuel S. Wilks, Professor of Mathematical Statistics, Princeton University. Charles I. Campbell of the National Academy of Sciences staff served as Secretary.—UBT

New "Modern Electroplating" Now Available

"Modern Electroplating" is now available from the publisher, and with its publication John Wiley & Sons launches a definitive series of books developed and sponsored by The Electrochemical Society. Allen G. Gray, technical editor of *Steel*, edited the new volume.

An integrated book containing the latest theory and practical aspects, "Modern Electroplating" originated as the published papers and discussions of the 1941 symposium of the Society. These and additional studies, completely revised and rewritten by 39 specialists, form the present work.

As a result of this combined effort, all the common metals and alloys and their accepted plating methods are covered. Uncommon metals and their potentials are also reviewed, and the specialized problem of plating on aluminum and magnesium considered. Each chapter is organized according to this pattern: principle; function of constituents of bath; operating conditions; maintenance and control; preparation of basis metals; and finishing of deposits.

Professor M. L. Holt of the Chemistry Department, University of Wisconsin, is assistant editor of the volume. The Editorial Advisory Board consists of William Blum, Charles L. Faust, A. Kenneth Graham, Henry B. Linford, Frederick A. Lowenheim, Harold J. Read, Ralph A. Schaefer, and Richard M. Wick. The new volume, containing 563 pages, is priced at $8.50, and can be obtained from John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y.

Members of The Electrochemical Society should send their orders for the volume direct to Society headquarters, 216 West 102nd Street, New York 25, N. Y., in order to obtain the 33⅓% discount given members. If a remittance of $5.67, payable to John Wiley & Sons, is included with the order sent to Society headquarters, members will not be billed for postage. However, members living in New York City must also include an additional 17¢ for city sales tax.

"The Corrosion Handbook," edited by H. H. Uhlig and published by John Wiley & Sons in 1948, was also sponsored by the Society and has therefore been included under the new official heading, The Electrochemical Society Series. Forthcoming volumes are planned which will be of interest to those already in the electroplating industry and also to industries that contemplate using electroplating processes to advantage.

Chemical Profession in Cleveland Makes Awards

The Fifth Annual Dinner of The Chemical Profession in Cleveland (sponsored by a joint committee representing The American Chemical Society, Alpha Chi Sigma, American Institute of Chemical Engineers, The Electrochemical Society, and American Institute of Chemists), was held on November 11, 1953 at the Hollenden Hotel, with more than 400 chemists and guests in attendance.

The feature address was given by Nobel Laureate, Professor Harold C. Urey, of The Institute of Nuclear Studies, University of Chicago, on the subject "Cosmic Chemical Engineering." Dr. Urey demonstrated the application of the disciplines and techniques of chemistry and chemical engineering in the study of the theories of the earth's origin, and emphasized the need of the chemists' cooperation with other sciences in determining the ultimate solution of this and other cosmological problems.

Four chemists were honored by their colleagues with The Cleveland Award for distinguished service to the chemical profession. The award recognized not only their personal scientific achieve-

ments, but especially their unselfish and persevering effort in promoting the effectiveness of the one or more professional societies which they have served. Dr. A. G. Bowers (President, The Gerson-Stewart Corporation) presented the certificates of merit to:

Gordon M. Juredine: Research chemist with The Harshaw Chemical Company; past chairman of The Cleveland Section, American Chemical Society; active member of The American Institute of Chemists; former editor of *Isotopics* (A.C.S. publication, Cleveland Section); served on the National Council of both A.C.S. and A.I.C.; and has been a leader in the fight for legal and professional recognition of chemists.

George W. Heise: National Carbon Company, retired in 1953; one of the founders of The Cleveland Section and also National President (1947) of The Electrochemical Society; a lifetime of active service to The Electrochemical Society, American Chemical Society, Alpha Chi Sigma, Sigma Xi, Faraday Society, and Phi Lambda Upsilon. Distinguished for his scientific achievements in industrial electrochemistry, and an elder statesman who encouraged and educated a great number of younger chemists to active service in the various chemical societies.

Raymond W. Erwin: National Carbon Company, retired in 1946; active leadership of numerous program committees to promote effectiveness of local sections of American Chemical Society, Electrochemical Society, Alpha Chi Sigma, and other Cleveland technical organizations. His 36 years' service, particularly in promoting the cooperation of chemical societies in civic activities, have done much to establish the prestige of the chemical profession in Cleveland.

Curry E. Ford: National Carbon Company; member of the ASTM, The Electrochemical Society, and American Institute of Chemical Engineers (past chairman, Cleveland Section, 1947). Particularly distinguished for active leadership in the latter organization, and in committee work in promotion of the technical and civic responsibilities of chemical engineers.

The fact that the nominations for the first Cleveland Award singled out three men from the same organization implicitly honors the policy of more than 30 years' duration of The National Carbon Company in encouraging the extracurricular activities and professional growth of chemists through their societies.

DIVISION NEWS

Theoretical Electrochemistry Symposium Scheduled for Chicago

The Theoretical Division of The Electrochemical Society is planning a symposium on "Special Methods in Electrochemistry" for the spring meeting of the Society in Chicago, May 2–6, 1954. The symposium will consist of both invited and contributed papers on such special phases as a-c electrolysis, amperometric techniques, oscillographic studies, tracer techniques, and the use of ultrasonics in electrochemistry.

Authors having material appropriate for this symposium should send five copies of a 75-word abstract to Society headquarters, 216 West 102nd Street, New York 25, N. Y., and a single copy of the abstract to Ernest Yeager, Vice-Chairman, Theoretical Electrochemistry Division, Department of Chemistry, Western Reserve University, Cleveland 6, Ohio, as soon as possible and certainly no later than January 15, 1954. Those desiring publication of their papers in the JOURNAL should submit three copies of the manuscript to Society headquarters.

SECTION NEWS

Chicago Section

The speakers for the October 2 meeting of the Chicago Section were three university students. The speakers and their subjects were:

1. E. P. Marbach, one of Professor H. J. McDonald's students in the Graduate School and Stritch School of Medicine of Loyola University of Chicago, "Some Clinical Chemical Applications of Electromigration in Stabilized Electrolytes."

2. R. E. Meeker, an Abbott Research Assistant to Professor Ralph Pearson of the Chemistry Department of Northwestern University, "Electrochemical Study of Fast Ionic Reactions."

3. M. E. Melnichak, working under Professor Warren Johnson of the Chemistry Department of the University of Chicago, "Detection and Determination of Chromium Ion Intermediates in Chromate Reductions."

At the November 6 meeting of the Chicago Section the advantages of a fast nuclear breeder reactor, as well as other interesting phases of atomic energy, were discussed by Dr. Frank G. Foote, Director of the Metallurgy Division of the Argonne National Laboratory.

Dr. Foote described the nature and type of metallurgical problems faced in the construction of nuclear reactors,

FRANK G. FOOTE

and presented some of the techniques used in solving these problems. Methods used in handling less known metals, such as zirconium, beryllium, and uranium, were discussed.

The corrosion problems faced in high temperature water systems were compared with those encountered in liquid sodium or sodium-potassium systems operating at high temperatures. It was pointed out by the speaker that although water is usually considered a relatively stable, noncorrosive substance when compared to such materials as the alkali metals, its use in high temperature stainless steel systems posed the more difficult corrosion problems. It was also pointed out that the eutectic mixture of sodium-potassium had the added advantage of a lower freezing point than water.

The meeting was followed by a discussion period. The questions asked indicated active interest on the part of the audience.

Officers of the Chicago Section for the 1953–1954 year are;

Chairman—H. T. Francis
Vice-Chairman—B. F. Freeberg
Treasurer—E. L. Koehler
Secretary—A. H. Roebuck, Argonne National Laboratory, Chicago

A. H. ROEBUCK, *Secretary*

India Section

The Second Technical Meeting of the Section for 1953 was held on September 28, 1953, at the Indian Institute of Science, Bangalore, with Professor

Brahm Prakash, Head of the Department of Metallurgy, Indian Institute of Science, in the chair in the unavoidable absence of Professor M. S. Thacker, Chairman of the Section. Dr. J. C. Ghosh, Director, Indian Institute of Technology, Government of India, Kharagpur, delivered a lecture on the electrolytic oxidation of organic compounds using porous carbon anodes. The speaker congratulated the India Section for its activities in spite of the limited membership, and expressed the hope that organizations of this type would function effectively as a liaison between research and industry in India. He then gave an account of the research work carried out in the Indian Institute of Science on the electrochemical preparation of some organic compounds; *p*-benzoquinone and chlorobenzene from benzene, ethylene chlorohydrin and ethylene glycol from ethylene, chloral from alcohol [Ghosh, *et al., J. Sci. Ind. Research* (*India*), **11B**, 356 (1952)]. The advantages of using thick-walled porous carbon anodes are: low cost; chemical inertia; catalysts can be deposited easily in the pores; the wicking action of the anodes offers attractive possibilities in electrolytic reactions in which compounds insoluble in aqueous electrolytes are to be used as cathodic or anodic depolarizers. The experimental details, operating conditions, use of catalysts, and the important results were described and illustrated. With a vote of thanks to the speaker, the meeting came to a close.

J. Balachandra, *Secretary-Treasurer*

New York Metropolitan Section

The Section met at dinner on November 18, and had as guest speaker Dr. L. G. Longsworth of the Rockefeller Institute for Medical Research. His topic was "Diffusion in Liquids and the Stokes-Einstein Relation."

Dr. Longsworth told of the long search for a method of measuring diffusion coefficients with a precision of 0.1% instead of the usual 1%. The method finally chosen was that of free diffusion in a modified Tiselius cell. An ingenious method was devised to obtain an initially sharp boundary between solution and solvent, and to correct for the small discrepancy from ideal sharpness. With a suitable optical system, spreading of the boundary could be followed by an analysis of Rayleigh interference fringes. Measurements were presented for a number of sugars, amino acids, and peptides in aqueous solution.

Dr. Longsworth showed how small variations in diffusion coefficients with concentration, even for these near non-electrolytes, could be detected by non-Gaussian distribution in the diffusing boundary; how empirical relations can be set up with molecular weight or molecular volume; and to what extent the Stokes-Einstein relation, strictly valid only for large, spherical, non-polar molecules in dilute solution, can be applied to the substances chosen for study.

Cecil V. King,
Member of the Executive Committee

Niagara Falls Section

The November 12th meeting of the Niagara Falls Section was a joint meeting with the National Association of Corrosion Engineers and was held at the Red Coach Inn at Niagara Falls.

J. C. Searer

Dr. J. C. Searer, Director of Resins Applications Research at Durez Plastics and Chemicals Incorporated, gave an interesting talk on "Modern Trends in Plastics."

Dr. Searer reviewed the increased use of synthetic resins and plastics during the past 25 years and presented comparative production figures for the common metallic materials. The effect of the tremendous increase in the amount and numbers of plastic materials on the chemical industries supplying the raw materials was discussed. Dr. Searer described and presented samples of the many various types of plastics, including plastics "alloyed" with other materials to give desirable properties.

John E. Currey, *Secretary*

Philadelphia Section

The Philadelphia Section was fortunate to have as its first speaker of the 1953–1954 season Dr. J. O'M. Bockris. Dr. Bockris, who comes from the Imperial College of Science and Tec nology, London, is currently Visiti Professor in Electrochemistry at t University of Pennsylvania. His tal entitled "Research Vistas in Electr chemistry," was given on November at the Harrison Laboratory of t University and was preceded by a enjoyable social hour and dinner at t Lenape Club. Some 50 members an guests attended the dinner and abou 75 persons were present at the talk.

In introducing his subject, Dr. Bock ris mildly scolded the industrialist (and academicians as well) for the lack of support of research and instruc tion in fundamental electrochemistry but he attributed this attitude to a understandable disappointment in th application of existing theories to mos electrochemical problems. These "tw most unfortunate historical coinc dences in electrochemical history" were, namely: (*a*) the early exploitation of Nernst's thermodynamic treatmen which led to attempted application far outside its validity even though it was unable to cope with real electrod processes; and (*b*) the introduction by Debye of the statistical ionic theory which was essentially a limiting theory and proved to be intrinsically inapplica ble to even moderately concentrated solutions. Consequently, it has been felt that a comprehensive theory o solutions of practical strength wa doomed to failure.

Since the beginning of the last war however, Dr. Bockris pointed out that there has been a considerable rebirth of interest in the field, largely as a result of many important new applications e.g., ion exchange, polarography, elec trophoretic separation of biologically important substances, etc., together with certain fundamental theoretical investigations, for example, those re lating to rate processes as applied to electrode potentials. A review of the literature during this period has shown a distinct trend toward a molecular-kinetic interpretation of electrode pro esses and a decline of the thermody namic viewpoint.

In stressing the growth and impor tance of the kinetic method Dr. Bockris described its success in furthering our understanding of two seemingly un related problems in electrochemistry (*a*) the mechanism of hydrogen evolution and (*b*) the structure of silicate melts. In the former it has aided in distinguishing between various likely mech anisms by permitting evaluation of significant numerical criteria. In the

ter it has rendered meaningful the served equivalent conductivity if rameters of rate equations connected th it are evaluated and related to mposition and structure. In brief,

J. O'M. Bockris

e findings point toward the formation anionic complexes for metals of small dius and high valency; this, together ith the constancy of the energy of tivation for viscous flow over more an one-half the range of composition r systems of the type M_xO_y-SiO_2, must ad us to reorganize our views regard- g such systems, since these results e entirely incompatible with the assical theory of liquid silicates in hich there are presumed to be infinite ains and sheets of Si-O-Si units.

In closing, Dr. Bockris listed four ubjects he felt to be of especial im- ediate interest in electrochemical search: (*a*) the application of recent heoretical developments in electrode inetics, (*b*) adsorption on solid sur- aces from solution; (*c*) theoretical volution of absolute galvanic potential ifferences; and (*d*) the mechanism of urrent transport through nerve fibers.

George W. Bodamer, *Secretary*

NEW MEMBERS

In November 1953 the following were elected to membership in The Electrochemical Society:

Active Members

John M. Finn, Jr., Horizons Incorporated, mailing add: 2734 Southington Ave., Shaker Heights, Ohio (Electronics and Theoretical Electrochemistry)

Alexander Hannah, Research and Development Division, Wyandotte Chemical Corporation, Wyandotte, Mich. (Corrosion, Electrodeposition, and Theoretical Electrochemistry)

Bertram C. Raynes, Horizons Incorporated, mailing add: 21950 So. Lake Shore Blvd., Euclid, Ohio (Electronics and Industrial Electrolytic)

Raymond H. Sevin, Miniere & Metallurgiques, mailing add: 86 Rue Cardinet, Paris, France (Electrothermic and Industrial Electrolytic)

William P. Shuman, Jr., Lehigh University, mailing add: 1609 Primrose Lane, Bethlehem, Pa. (Battery and Theoretical Electrochemistry)

Walter G. Zelley, Aluminum Research Laboratories, mailing add: 168 Jefferson Ave., New Kensington, Pa. (Electrodeposition)

GASTON F. DuBOIS

Gaston F. DuBois, prominent consulting engineer, and former officer and director of Monsanto Chemical Company, died at Barnes Hospital in St. Louis, Missouri, on November 1.

Born at LeLocle, Switzerland, August 9, 1880, Mr. DuBois was educated at the Federal Polytechnic Institute at Zurich, Switzerland, from which he received a degree in chemical engineering in 1903. This was followed by a postgraduate course in electrochemistry at the Technische Hochschule, Dresden, Germany.

Recognized as one of the foremost figures in the development of the American chemical industry, Mr. DuBois was the recipient of many awards, culminating in 1943 in the Perkin Medal, the chemical industry's highest honor.

Among his numerous achievements was the first successful commercial production in this country of caffeine, glycerophosphates, and bismuth metal; he was active in the research of many basic compounds such as rubber chemicals, plasticizers, resins, and pharmaceuticals. He was also one of the few men instrumental in making the United States independent of foreign supplies of critically needed dyes and drugs during World War I, generally recognized as the real beginning of the chemical industry here.

Mr. DuBois had been associated with the Monsanto Chemical Company since 1904 as production manager, vice-president, technical director, president, and vice-president in charge of research and development, respectively. In 1939, he became a member of the company's executive committee. He retired in 1945, but remained as a member of the Board of Directors until 1949.

Mr. DuBois joined The Electrochemical Society in 1929.

LETTER TO THE EDITOR

What! No Flashlight?

Dear Sir:

Through the kindness of O. W. Storey, I have before me the startling definition of the dry cell as it appears in The Van Nostrand Chemists Dictionary, D. Van Nostrand Company, Inc., New York, 1953:

> DRY CELL. A small electric battery widely used to supply small electric currents at low voltages, for radio sets, bell circuits, and various alarm systems and control devices. It consists of a central carbon anode, and of a zinc cup acting as cathode, and container for the cell. The electrolyte is a wet paste of ammonium chloride, with some zinc chloride, and manganese dioxide (depolarizer).

Which brings to mind a quotation from John Masefield (Sonnets. 14) culled by M. R. Hatfield some years ago:

> ". . . A thing of watery salt
> Held in cohesion by unresting cells
> Which work they know not why . . ."

Further comment seems superfluous. I had a hard time deciding whether to send this to you or to the Van Nostrand editors. You lost.

G. W. H.

BOOK REVIEWS

Elektrochemie — Theoretische Grundlagen und Anwendungen by G. Milazzo; revised and translated into German from the first Italian edition. Springer, Vienna, 1952; XIII + 419 pages, $8.60.

The original Italian edition of this book appears to have had a successful career as a text for university courses. Professor Milazzo is himself in charge of the teaching of electrochemistry at the University of Rome and his course, as represented by the book, establishes a rational balance between electrochemical principles (including thermodynamic foundations, properties of electrolytic solutions, galvanic cells, electrode potentials, etc.) and the various applications to analytical chemistry, electrometallurgy, industrial electrochemistry, etc. There are separate chapters on experimental methods, the electrolysis of molten salts, primary and secondary cells, the electrochem-

istry of colloids and electrokinetics, and the electrochemistry of gases. The great abundance of tables of numerical data is a particularly welcome feature.

Besides a warm introduction by Professor Bonino of Bologna, the German edition is presented by Professor Wolfgang Pauli Sr. of Zurich at whose suggestion Dr. Schwabl of Vienna undertook the translation. Professor Pauli felt that this book was unique in its covering of the whole of electrochemistry in a manner conveniently accessible to workers in other fields. At the same time it offers a compact, reasonably accurate, and up-to-date account of electrochemistry even for the specialist. That these functions are well fulfilled by Professor Milazzo's book seems to be demonstrated by its favorable reception in several foreign countries. In the U. S. the theoretical portion of the book may be regarded by some as differing somewhat from our set ways of presenting electrochemistry, but the availability under one cover of electrochemical theory, practice, and applications should make this treatise a desirable addition to any scientific library.

The book is attractively presented and beautifully printed on excellent paper.

PIERRE VAN RYSSELBERGHE

ELEMENTS OF HEAT TREATMENT by George M. Enos and William E. Fontaine. Published by John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, London, 1953. 286 pages, $5.00.

This well illustrated book is a practical introduction to the heat treatment of metals—primarily steels. It is not a book for the metallurgical specialist or the metal physicist. It is written in simple language and is well suited to the needs of beginners, design and mechanical engineers, and all those who want a clear deliberately uncomplicated review of basic metal treating techniques.

The content of the book is as follows:

1. The first one-sixth of the book presents a very brief introduction to the ideas of crystal form, of microstructure and phase diagrams, and a complete but equally brief account of the mechanical testing of metals. These short sections seem just about adequate to their purpose.

2. The middle two-thirds or more of the book is devoted to steel and its heat treatment. Here the coverage is very thorough indeed. Concepts and techniques ranging from classification of steels, through hardenability, to surface hardening are well described, asually without reference to mechunisms.

3. The last two chapters are devoted to rather short discussions of heat treatment of nonferrous alloys and of equipment and methods used in practice.

It is believed that the attempt of the authors, as stated by them in their preface, to set down the fundamental theory involved in the heat treatment of metals has been substantially achieved.

E. E. SCHUMACHER

RECENT PATENTS

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

September 22, 1953

Willard, A. R., 2,652,617, Machine for Manufacturing Battery Plates

Brennan, J. B., 2,653,119, Plates Adapted for Use in Electrolytic Devices

Greig, H. G., 2,653,126, Method of Marking

Brenner, A., and Burkhead, P., 2,653,127, Methods of and Baths for Electrodepositing Cobalt or Cobalt-Molybdenum Alloys

Brenner, A., Burkhead, P. S., and Sentel, C. A., 2,653,128, Method of and Bath for Electrodepositing Tungsten Alloys

Ruffle, W. H., 2,653,178, Thermocouple Device

Baldwin, J. H., 2,653,179, Primary Battery and Method of Making the Same

Hignett, H. W. G., and Hersch, P., 2,653,180, Alkaline Storage Battery and Process for Preventing its Self-Discharge

Ballard, R. J., 2,653,266, Vapor Electric Device

Vokac, C. W., Rothenberger, G. M., and Morey, W. A., 2,653,269, Hydraulic-Electrical Apparatus for Automatically Regulating the Position of Direct Arc Electric Furnace Electrodes

Huge, H. M., 2,653,293, Battery Charger

September 29, 1953

Gregory, E. D., Lilliendahl, W. C., and Wroughton, D. M., 2,653,869, Manufacture of Ductile Vanadium

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Ejersted, J. and Bockman, O. C., 2,653,878, Process for the Production of Electrodes

Annerud, S. A., 2,653,905, Process for Total Treatment of Copper-Containing Iron Pyrites

Fitzer, G., 2,653,906, Anticorrosion Needle Mounting

West, S. G., 2,653,983, Thermocouple Unit

Godeas, M. S., 2,653,984, Electric Storage Battery

Philipps, T. E., 2,653,985, Battery Plate Separator

Philipps, T. E., 2,653,986, Battery Plate Separator

Daty, J. A., 2,653,987, Porous Material Useful in Battery Separators

Rupp, J. L., 2,653,988, Storage Battery and Mounting and Connection Means Therefore

Wright, D. A., 2,654,045, Thermionic Cathode for Electric Discharge Devices

October 6, 1953

Thierfelder, C. W., 2,654,675, Luminescent Screen Composition

Calderon, E. R., and Slomin, G. W., 2,654,701, Plating Aluminum

De Long, H. K., 2,654,702, Electrodeposition of Metal From Alkaline Cyanide Bath

Brown, H., 2,654,703, Electrodeposition of Bright Nickel, Cobalt, and Alloys Thereof

Brown, H., and High, L. R. B., 2,654,704, Electroplating of Nickel

Case, B. C., 2,654,705, Nickel Plating

Gaylor, P. J., 2,654,706, Electrolytic Regeneration of Spent Caustic

Saffel, D. E., 2,654,707, Anodizing Rack

Saugg, S., 2,654,794, Sealed Storage Cell and Battery and Method of Manufacturing the Same

Brill, O. H., and Solomon, F., 2,654,795, Electrode for Electric Batteries and Method of Making Same

Goodrich, R. R., 2,654,852, Photoconductive Target for Cathode-Ray Devices

Weimer, P. K., 2,654,853, Photoelectric Apparatus

Petersen, C. C., 2,654,862, Cell for Electrical Measurement of Liquid Dielectrics

October 13, 1953

Donath, G. A., 2,654,939, Storage Battery Grid Plate Casting and Trimming Machine

Gullett, W. W., 2,655,456, Manganese Dioxide for Primary Cells

Chester, A. E., 2,655,471, Chromium Electroplating

Hilliard, R. V., and Baroch, C. T., 2,655,472, Process of Extracting and Recovering Metals by Leaching and Electrolysis

Lowenheim, F. A., 2,655,473, Electrolytic Detinning

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